About the Cover

The world's fastest supercomputer, BlueGene/L, and an image from groundbreaking research on hydrogen serve as a backdrop for Lawrence Livermore's main administration building.

About the Lab

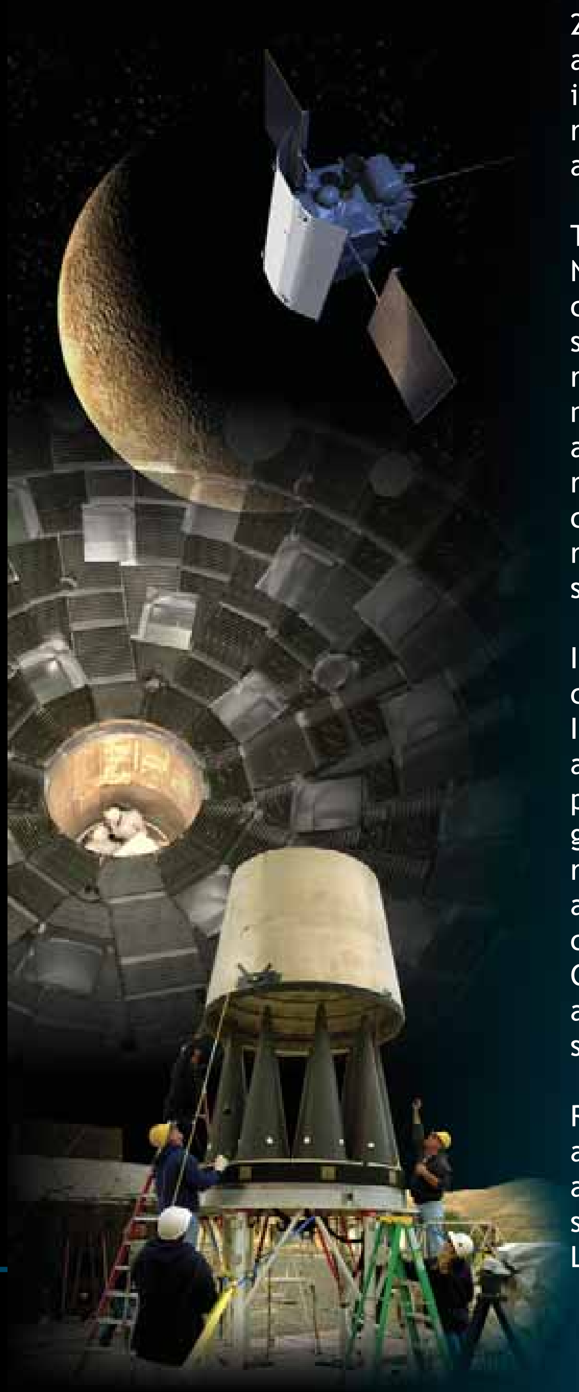
Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons research facility. The Laboratory has been managed since its inception by the University of California, first for the Atomic Energy Commission and now for the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy. Through its long association with the University of California, the Laboratory has been able to recruit a world-class workforce and establish an atmosphere of intellectual integrity and innovation, both of which are essential to sustained scientific and technical excellence. As an NNSA national laboratory with about 8,000 employees, Livermore has an essential and compelling core mission in national security and the scientific and technical capabilities to solve nationally important problems.

What's Inside

2004 Annual Report

A Message from the Director

Michael R. Anastasio



For the staff of Lawrence Livermore National Laboratory,

2004 was a busy and highly successful year. As our many accomplishments in this annual report illustrate, Livermore is a vibrant national laboratory, continually changing and reinventing itself to achieve demanding mission objectives and meet emerging challenges.

The Laboratory is part of the Department of Energy's National Nuclear Security Administration (DOE/NNSA) through a contract with the University of California, and national security is our primary mission. Livermore's foremost responsibility is ensuring that the nuclear weapons in the nation's smaller 21st-century stockpile are safe, reliable, and secure. In support of stockpile stewardship, Laboratory researchers are applying remarkable new experimental and computational capabilities to better assess weapon performance, resolve issues, and refurbish weapons to extend their stockpile life.

In 2004, we completed our first highly successful experimental campaigns using the first 4 (of 192) beams of the National Ignition Facility (NIF), the world's largest laser. Researchers also obtained outstanding data characterizing plutonium at high pressure from the first year of tests at the JASPER two-stage gas gun. In addition, IBM delivered the first quarter of the revolutionary BlueGene/L supercomputer to Livermore in 2004, and that segment alone set the record as the world's fastest computer. Acquired through NNSA's Advanced Simulation and Computing Program, Purple (another machine arriving in 2005) and BlueGene/L will markedly improve our ability to sustain a safe and effective nuclear deterrent.

Reducing the threat posed by the proliferation, terrorist acquisition, or use of weapons of mass destruction (WMD) is an essential and enduring aspect of the Laboratory's national security mission. This growing mission area is an example of Livermore anticipating a threat and starting research before the threat emerged. Our efforts provide valuable assistance to the U.S. government in preventing, detecting, and responding to the WMD activities of others. The Laboratory develops advanced technologies such as our Autonomous Pathogen Detection System, which monitors for the presence of biological agents and can operate without human intervention for more than a week. Our RadScout portable radiation detector was quickly transferred to U.S. industry and is now available to field inspectors.

Livermore also provides unique expertise, integrating analyses, and operational support with capabilities such as the National Atmospheric Release Advisory Center (NARAC). It is the premier capability in the U.S. for real-time assessments of the atmospheric dispersion of hazardous materials. In 2004, NARAC was designated by the Department of Homeland Security (DHS) as the primary interim provider for the Interagency Modeling and Atmospheric Assessment Center. DHS also opened at Livermore its Biodefense Knowledge Center, a multilaboratory collaboration to provide in-depth analysis of biodefense issues.

In response to broader emerging threats to global security, Livermore pursues breakthrough scientific and technical advances to meet pressing needs for environmental quality, clean energy, better water management, and improved human health. This annual report features recent progress in explorations ranging in scale from biomolecules to the Earth's climate. These activities—and our basic science research—make use of the Laboratory's special facilities and multidisciplinary capabilities. Livermore's intellectual climate is enriched by pursuing research for multiple purposes, such as radiation detection technologies for both national security and space science, and bioscience for biosecurity and better human health.

Lawrence Livermore is a special place because of its national security mission. All employees shoulder extraordinary responsibilities to work safely and securely, and the Laboratory must be protected against evolving threats. Safety and security are the most important consideration in day-to-day operations, and they are integrated into all programmatic work planning and execution. We work to continually improve not only safety and security but all aspects of Laboratory operations.

Our efforts received recognition in 2004. External reviews gave high marks for Livermore's protective forces, cyber security, counterintelligence, facilities management, and selected business practices. Formal public health assessments of the Laboratory's sites found no apparent public health hazards. In work safety, the NIF construction project completed its fourth consecutive year (four million hours) without a lost work day from on-the-job injury. However, in all areas we can do still better. We have launched a Process Improvement Initiative to identify and address key opportunities and needs to work more safely, securely, and efficiently.

Continual change and reinvention to meet evolving challenges would not happen without contributions from all Laboratory employees. An outstanding, dedicated staff is the key to our successes. One of my top priorities is workforce management—making sure that we recruit a talented, diverse staff and offer career growth opportunities for everyone. Exceptional people make Livermore an exceptional national laboratory.

This year, my senior management team will be working with future leaders across the Laboratory to refine our shared vision of Livermore's future. Our goal is to formulate and implement a set of near-term initiatives that will put us on a path to this future. As our process of reinvention and change continues, we will sustain our focus on important national objectives and a commitment to public service and excellence. We are excited to take on the opportunities and challenges the future offers.

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Nuclear Weapons Stewardship

Nuclear Weapons Stewardship

Lawrence Livermore National Laboratory was established in 1952 to help ensure national security through the design, development, and stewardship of nuclear weapons. National security continues to be the Laboratory's defining responsibility. Livermore is one of the three national security laboratories that support the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE).

Livermore plays a prominent role in NNSA's Stockpile Stewardship Program for maintaining the safety and reliability of the nation's nuclear weapons. The Stockpile Stewardship Program integrates the activities of the U.S. nuclear weapons complex, which includes Lawrence Livermore, Los Alamos, and Sandia national laboratories as well as four production plants and the Nevada Test Site. As the nuclear weapons in the U.S. stockpile continue to age, Laboratory scientists and engineers are challenged to ensure the weapons' performance and to design refurbishments for them as necessary without conducting nuclear tests.

Working with the other NNSA laboratories, Livermore is attending to the immediate needs of the aging stockpile through assessments and actions based on a combination of laboratory experiments and computer simulations of nuclear weapons performance. In addition, the Laboratory is acquiring more powerful experimental and computational tools to address the issues that will arise as the nation's nuclear weapons grow older. These vastly improved scientific capabilities will contribute to NNSA's goal of transforming the nuclear weapons complex, making it more responsive to the need for a smaller stockpile that is even safer, more secure, and easier to maintain.

Certifying Stockpile Safety and Reliability

Livermore is a key participant in formal review processes and assessments of weapons safety, security, and reliability. In 2004, the Laboratory completed its reviews for the ninth cycle of the Annual Assessment process. This annual certification of the stockpile was first mandated by the president, and it is now required by law as a result of congressional legislation. The formal process is based on the technical evaluations made by the three laboratories and on advice from the laboratory directors, the commander-in-chief of the Strategic Command, and the Nuclear Weapons Council. To prepare for this process, Laboratory scientists and engineers collect, review, and integrate all available information about each stockpiled weapons system, including physics, engineering, chemistry, and materials science data. This work is subjected to rigorous, in-depth, intralaboratory review and expert external review, including formal use of red teams.

For the Annual Assessment Review—and the formal certification of refurbished warheads—weapons experts depend on an extensive range of aboveground testing, vastly improved simulation capabilities, and the existing nuclear test database. This information is essential input for a formal methodology called quantification of margins and uncertainties (QMU). Livermore and Los Alamos developed QMU to serve as the basis for formal certification actions and for evaluating the significance of unexpected results from stockpile surveillance and other sources. The methodology, which entails the development and application of a rigorous set of quantitative standards, is analogous to the use of engineering safety factors in designing and building a bridge.

The National Nuclear Security Administration's principal deputy administrator, Jerald Paul (second from right), and Laboratory director Michael Anastasio (right) are briefed on stockpile stewardship experiments at the High Explosives Applications Facility.

The two laboratories continue to refine QMU while implementing the methodology in current warhead assessment activities. The QMU approach was first applied in Livermore's certification of the design changes to refurbish and extend the life of the W87 intercontinental ballistic missile (ICBM) warhead. The methodology is now serving as the central integrating theme in Livermore's certification plans for life extension of the W80 warhead.

W87 Warhead Life Extension Complete

In November 2004, NNSA completed its first program to extend the lifetime of a stockpiled nuclear weapon system when the final refurbished W87 ICBM warhead rolled off the assembly line at the Pantex Plant. The program proved to be a successful example of stockpile stewardship in the absence of nuclear testing, and provides a model of the processes to be followed by ongoing and future life-extension programs. Refurbishment of the W87 ICBM warhead—the design in the stockpile with the most modern safety features—enhances the weapon's structural integrity and extends its life by 30 years.

Congress authorized the W87 Life Extension Program in 1994. Livermore, which designed the W87, was tasked with developing and certifying the engineering design of the W87 modification. Design development activities included a combination of

W87 engineering test units at Site 300.

nonnuclear experiments, flight tests, physics and engineering analyses, and computer simulations. An important milestone was achieved on schedule in 1999 when the first rebuilt W87 was delivered back to the Department of Defense (DoD).

NNSA and DoD established an extensive technical review process to certify the design changes and production procedures. The process entailed thorough internal reviews at Livermore, technical reviews by DOE/NNSA (including peer review by Los Alamos), and reviews by DoD. Lawrence Livermore and Sandia national laboratories completed formal certification in 2001. Throughout the program, the Laboratory collaborated with the production plants, working to ensure the quality of the W87 refurbishment work.

W80 Life Extension

In October 2004, NNSA formally transferred stockpile responsibility for all W80 cruise missile warheads from Los Alamos to Livermore to better balance the workload between the two laboratories. The W80, designed by Los Alamos, is currently deployed in air-launched and sealaunched cruise missiles. Livermore has developed and is now executing detailed surveillance plans to monitor the condition of stockpiled warheads.

Some of the W80s will undergo refurbishment. Lawrence Livermore and Sandia (California) national laboratories had already been assigned to carry out the W80 Life Extension Program in 2001.

An extensive program of experimental and computational activities is under way in support of a schedule that calls for first production of the refurbished W80 warheads in fiscal year 2009. Livermore, Sandia, and the Air Force partnered to perform four captive-carry flight tests in 2004 to collect thermal and structural performance information. In addition, Laboratory scientists performed numerous high-resolution two-dimensional (2D) and three-dimensional (3D) computer simulations to design and test new components, predict system performance, and prepare for certification of the proposed modifications. The simulations have also assisted in the preparation of experiments, and the tests, in turn, provide data to compare with model predictions.

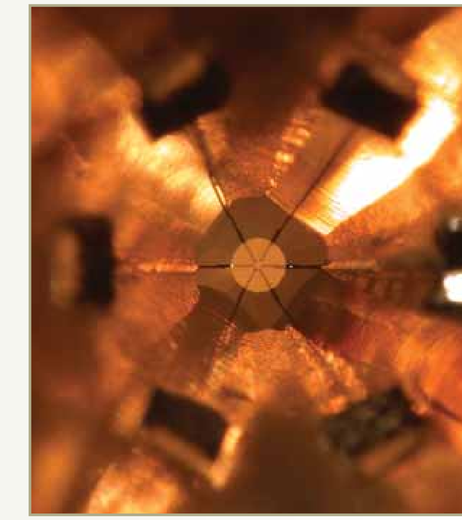
A particularly important part of the W80 Life Extension Program is hydrodynamics testing, in which scientists study the performance of mock weapon primaries as their pits are imploded by high explosives. Most hydrodynamics experiments are carried out in the Contained Firing Facility at Site 300, the Laboratory's experimental test area 24 kilometers southeast of the main site. In 2004, Livermore researchers performed five large-scale, integrated hydrodynamics experiments, including one experiment carried out at the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos. Many of these tests were in support of the W80 Life Extension Program. The W80 hydrodynamics tests are showing impressive agreement with predictions from computer simulations.

The Contained Firing Facility at Site 300.

Experiments to Understand Plutonium

With 15 successful shots, 2004 proved to be a banner year for the Joint Actinide Shock Physics Experimental Research (JASPER) facility at the Nevada Test Site. Livermore took the lead for NNSA in constructing JASPER and bringing it into operation as a multilaboratory user facility. JASPER is a 30-meter-long, two-stage gas gun that accelerates a projectile to speeds of up to 8 kilometers per second. The impact of the projectile produces an extremely high-pressure shock wave (about 600 gigapascals or 6 million atmospheres) in the targeted material and raises its temperature to as high as 7,000 kelvins. The facility is designed to accommodate experiments to study uranium, plutonium, and other hazardous materials. A primary target chamber houses the target and contains the experimental debris for environmentally safe disposal.

The Joint Actinide Shock Physics Experimental Research gas gun at the Nevada Test Site.



A "designer" diamond anvil cell.

Plutonium is an extremely complex material, and it is critically important to the functioning of nuclear weapons. Comprehending the detailed properties of plutonium metal and alloys is one of the major scientific challenges in the Stockpile Stewardship Program. Through precise measurements taken in a series of JASPER experiments, scientists are able to reconstruct the Hugoniot curve—the relationship between the exerted pressure and the velocity of the shock wave in a plutonium sample. They have also developed an approach to providing more complex pressure pulses that mimic actual weapon implosions. This information helps researchers to improve plutonium equation-of-state models used in weapon performance calculations.

Laboratory experiments using diamond anvil cells complement the shock physics experiments. A diamond anvil cell is a small mechanical press that squeezes a microgram of material between two small flat-tipped diamonds, attaining pressures on the order of 100 gigapascals. In diamond anvil experiments fielded at the Advanced Photon Source at Argonne National Laboratory, Livermore scientists found the first evidence of a new high-pressure structure of plutonium that had been predicted years ago. The experiments were conducted at a special beam line for high-pressure material studies that was developed by a consortium of researchers from Lawrence Livermore, Argonne, the University of Nevada, and the Carnegie Institute of Washington. In February 2004, Livermore scientists performed the first experiments in which new and aged samples of plutonium were tested in the same diamond anvil cell to provide side-by-side comparisons.

Researchers at the Laboratory have also begun fielding experiments that use "designer" diamond anvil cells. These cells include diagnostic microcircuits, made of tiny tungsten wires,

Air, Water, and . . . Hair Spray?

A fraction of the shots fired at the Contained Firing Facility contain beryllium, a metal that is used in some nuclear weapons. Because beryllium can be harmful to the health and safety of workers as an airborne particulate, the issue arose: how best to clean up the firing chamber after explosive experiments. Livermore's Hazards Control came up with a novel solution. First purge the contaminated air and then thoroughly wash out the facility. Much of this work can be performed remotely. However, even after this washdown, some beryllium remains imbedded in the chamber's walls and could become airborne during set up for the next experiment. To immobilize these particulates in place, Hazards Control recommended spraying the chamber walls with an encapsulating solution that is similar in formula to hair spray.

that are tailored to reveal new information about how the structure of materials and electrical and magnetic properties change in response to increasing pressure. Recent improvements in diamond synthesis technology make it possible to fabricate microcircuits within the diamond anvils.

Livermore's designer diamond anvil experiments are focusing on lanthanides and actinides, which include uranium and plutonium. The goal is to obtain data about the complex behavior of the material's electrons that standard diamond anvil cell techniques and dynamic experiments cannot supply. In the first experiments on manganese oxide, which is an insulator under normal conditions, researchers found that the material makes a sharp change to metallic behavior as pressure is increased to above 90 gigapascals. The transition is marked by a nearly 10-percent reduction in volume as the crystalline structure breaks down and electrons become delocalized. Similar behavior has been observed in two lanthanides, but no significant changes in electrical conductivity have been observed in experiments on depleted uranium.

National Ignition Facility Project

Major progress continues to be made on construction of the National Ignition Facility (NIF). At the same time, the NIF team continues its outstanding safety performance (see p. 35). The NIF project is meeting all of its technical performance, cost, and schedule milestones. Upon completion in 2008, NIF's 192-beam laser system will be used to compress fusion targets to conditions required for thermonuclear burn, liberating more energy than that required to initiate fusion reactions. Inertial confinement fusion energy is a long-standing program goal within DOE. Current plans are to begin the necessary preignition experiments on NIF in fiscal year 2009 and to conduct the first ignition experiments in fiscal year 2010. As part of the fiscal year 2005 budget process, Congress has directed changes that affect the funding profile for NIF programs. Target goals for finishing the project and beginning ignition experiments are being evaluated with respect to these changes.

NIF will offer researchers the capability to study physical processes at temperatures approaching 100 million degrees and 10 billion atmospheres, conditions that exist naturally only in the interior of stars and in exploding nuclear weapons. These temperatures and pressures are needed to validate weapons-physics computer codes and address important issues of stockpile stewardship. In addition, NIF will allow laboratory studies of astrophysics and materials under conditions similar to those found in stars.

The National Ignition Facility (NIF) at night.

Inside NIF's target chamber.

NIF Experiments

In 2004, researchers performed experiments using NIF's first four laser beams (called a quad). The beams were commissioned in December 2002 as part of a program called NIF Early Light. This program completed a quad of beams for laser performance and experimental campaigns, and by October 2004, nearly 400 full system shots had been performed. NIF Early Light validated the laser system's ability to meet the project's Completion Criteria as well as its Functional Requirements and Primary Criteria. NIF meets performance criteria for beam energy and power output, beam-to-beam uniformity and timing, and delivery of shaped pulses for ignition and nonignition experimental needs.

With just 4 of its 192 beams in operation, NIF is already the highest energy infrared laser in the world. NIF has also set world records for green and ultraviolet laser energy produced on a single beam. Overall, the NIF laser system has demonstrated ultraviolet laser energy equivalent to 2 million joules (MJ) in all 192 beams, which exceeds the specified design requirement of 1.8 MJ.

Scientists from Livermore and Los Alamos conducted the first joint NIF experiments in support of stockpile stewardship, meeting a high-level milestone set by NNSA. In these hydrodynamics experiments, intense laser light illuminated a planar target to create a turbulent 3D jet of hot, supersonic aluminum directed into a low-density carbon foam. The time evolution of the jet was studied using a suite of new diagnostic capabilities commissioned to support these experiments. The results are being used as a benchmark for new hydrodynamics codes at both laboratories. In the first experiments, 2D jets were created to demonstrate the fidelity and reproducibility of the NIF experimental platform. Then scientists acquired data on the behavior of single 3D jets entering the foam at an angle and double jets of different sizes interacting with each other.

Completion of another series of experiments met the first milestone of the Inertial Confinement Fusion Program on NIF. Ultraviolet light from NIF's first quad of lasers was precisely aimed at gas-filled targets in the center of the target chamber. The target size was equivalent to the laser beam path length in a hohlraum for a fusion ignition experiment. The tests showed qualitative agreement between calculations and the observed beam propagated through the target. They also demonstrated the effectiveness of new NIF diagnostics that include the first of three planned full-aperture backscatter stations (FABS), which measure the laser light scattered from the target back through the final focusing lens. The FABS are important for understanding laser–plasma interactions in NIF targets.

Livermore and Los Alamos scientists also conducted experiments on hohlraum energetics. Using subscale half-hohlraums, or

The NIF control room.

"halfraums," researchers measured temperatures of over 300 electronvolts and studied the time evolution of plasma formation in the halfraums. These results verify that NIF's laser beams can be precisely conditioned and pointed to deliver energy into hohlraums. The United Kingdom's Atomic Weapons Establishment (AWE) provided a key diagnostic for measuring the production of energetic electrons. Researchers from Sandia National Laboratories and AWE also participated in this experimental campaign.

Development of advanced diagnostics is an important component of the overall effort at NIF. In addition to the measurement capabilities used for the aforementioned experiments, the NIF team installed and commissioned the velocity interferometer system for any reflector (VISAR) in 2004. Developed by scientists from Livermore, Los Alamos, and Bechtel Nevada, VISAR measures the reflection from a shock front generated by a laser-irradiated target. It will be used to perform equation-of-state experiments.

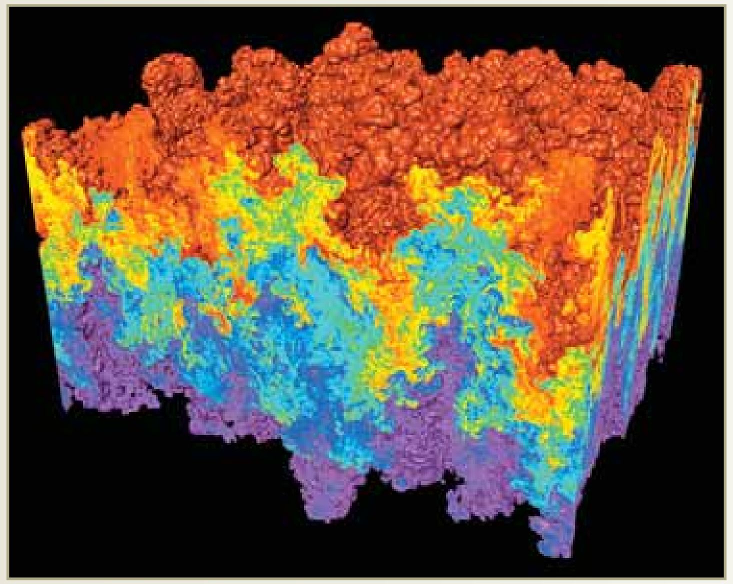
Computer Modeling and 3D Visualizations

In 2004, Livermore researchers used super-computer simulations of nuclear weapons performance and safety to support the Annual Assessment process, pursue the W80 Life Extension Program, and provide peer review and independent assessments of Los Alamos's weapons activities. Simulation results provide data to design stockpile-related experiments and interpret their results. In other cases, codes are tested through comparison with experiments, and once verified, they are used to predict the results in regimes where experiments cannot be performed.

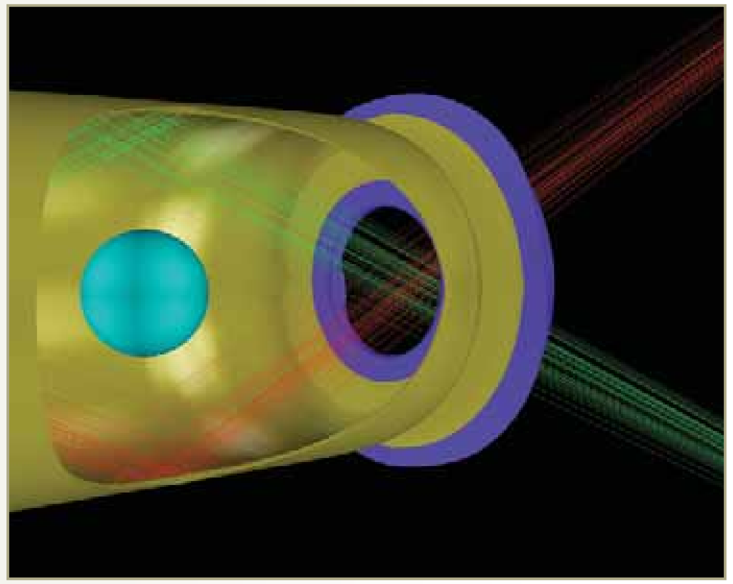
A variety of simulation codes are used to model relevant physical processes. An example is the Livermore-developed hydrodynamics code MIRANDA for studying the behavior of instabilities that evolve when materials of different densities are accelerated. Weapons physicists use MIRANDA simulations to better understand the physics involved in several stockpile stewardship issues. Another code, HYDRA, is helping in the design of targets for NIF. HYDRA can simulate, from first-principles physics, the entire fusion ignition process in three dimensions, including calculation of the radiation, electron, ion, and charged-particle transport and hydrodynamics.

Computer modeling is also an invaluable component of efforts to better understand materials in weapons—how they age and how they perform under extreme conditions of pressure and temperature. As an example, the Laboratory is making great progress in studying the strength properties of materials and how they dynamically fracture under high strain. In addition, Livermore scientists performed the first quantum molecular dynamics simulation for any actinide—uranium. (See p. 23 for examples of other quantum mechanical simulations.) This work is part of an integrated effort to develop vastly improved multiphase equations of state for plutonium, uranium, and other heavy elements.

To interpret the results of simulations, scientists depend on capabilities being developed through Livermore's Visual Interactive Environment for Weapons Simulation



The MIRANDA code simulates the instability of two fluids mixing.



The HYDRA code simulates an ignition target for NIF.

2004 Annual Report

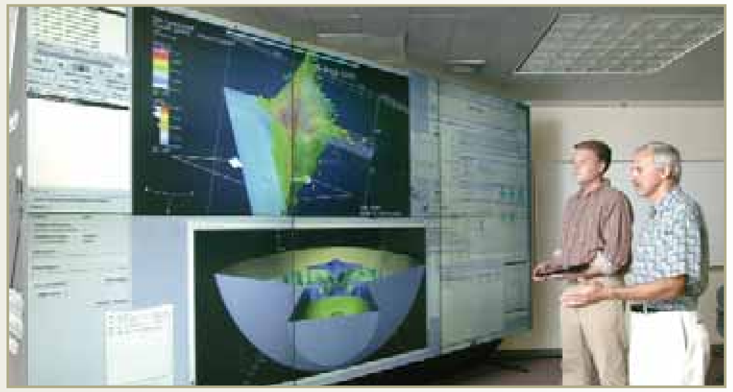
(VIEWS) Program. A key advance was the development of Linux-based visualization clusters, which farm out problems in pieces to hundreds or thousands of microprocessors networked together and working in parallel. Clusters offer substantially more power and speed, and they cost much less than the proprietary systems they replace. With 64 nodes consisting of 2 processors and a graphics card, the Production Visualization Cluster, which first went online in 2002, has served as a model to develop even more powerful clusters, such as gViz.

A software architecture called Chromium provides a way for interactive 2D and 3D graphics applications to take full advantage of visualization clusters and efficiently produce images from enormous sets of data. An R&D 100 Award winner in 2004, Chromium was developed by two Laboratory researchers working with colleagues from Stanford University, the University of Virginia at Charlottesville, and Tungsten Graphics, a private firm.

The World's Most Powerful Computer

November 2004 marked delivery from IBM of the first racks of BlueGene/L. This first segment—one-fourth the size of the ultimate machine—immediately captured the number-one spot on the

A visualization using the Chromium software program.



At left, the gViz visualization engine developed through Livermore's Visual Interactive Environment for Weapons Simulation Program. Below, one of two large powerwalls at the Terascale Simulation Facility.

Top500 list of the world's fastest supercomputers, clocking 70.72 trillion operations per second (teraops) on the industry-standard LINPACK benchmark. When complete in the summer of 2005, BlueGene/L will have 65,536 nodes and a peak performance rating of 360 teraops. It is a world apart from other scalable computers not only in terms of performance but also in size, cost, and design. Compared with the previous world record holder, BlueGene/L is eight times as fast, costs one-fourth as much, occupies one-tenth the floor space, and consumes one-sixth the power.

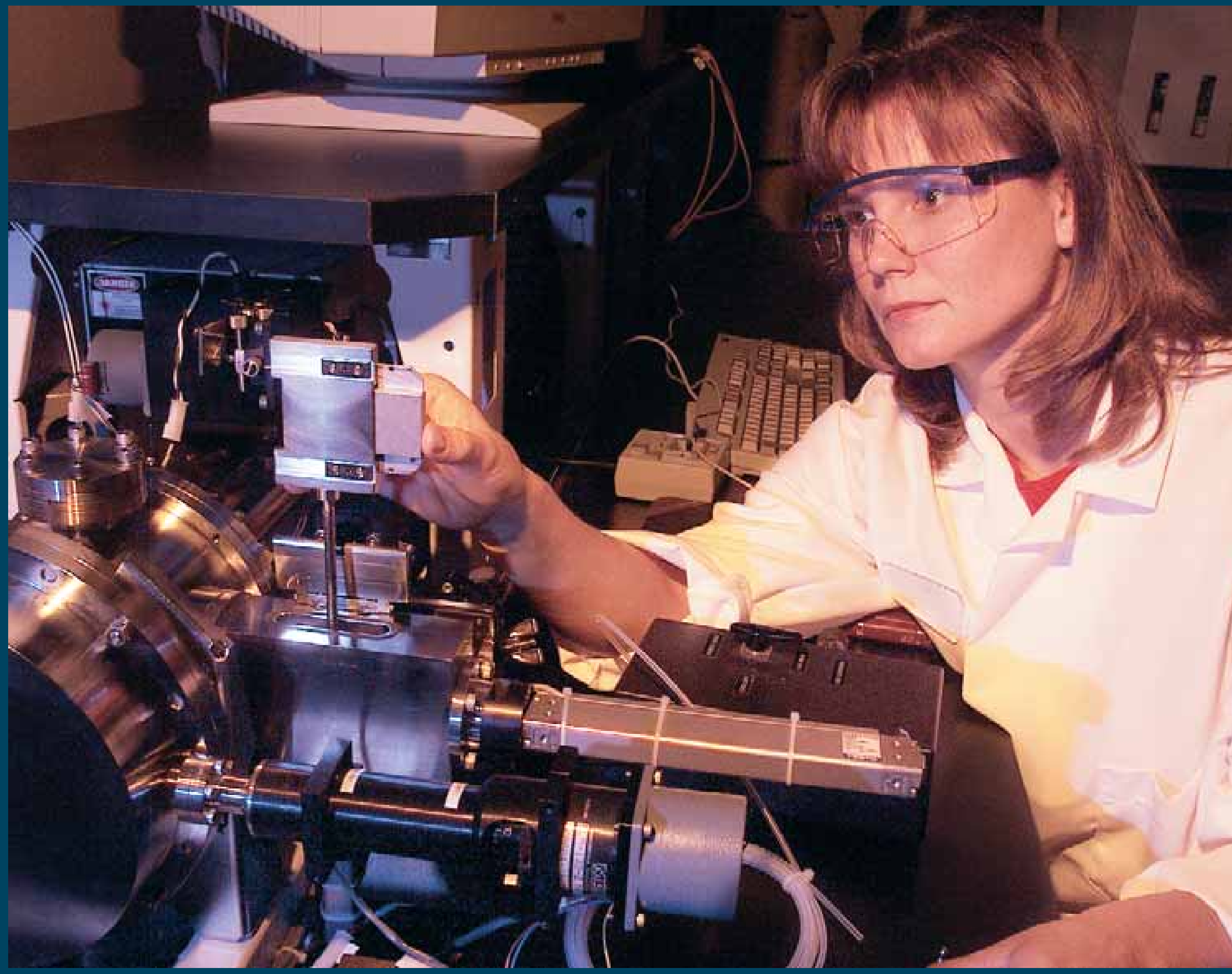
BlueGene/L will support stockpile stewardship by performing simulations of materials at the atomic and molecular scales and hydrodynamics calculations of turbulence, shock, and instability phenomena. It will also serve as a computational research machine for evaluating advanced computer architectures. Experience gained working with BlueGene/L may also help define the path to affordable petaops computing in the 2008 timeframe.

ASC Purple, operating at 100 teraops, will also arrive from IBM in 2005. Based on a more mature and proven technology, the machine will provide a highly reliable production environment for the Stockpile Stewardship Program and enable 3D simulations with high-fidelity physics models of the performance of a full nuclear weapon system. ASC Purple will be powered by 12,544 microprocessors in 196 individual computers interconnected via an extremely high-bandwidth, superfast data highway.

Both BlueGene/L and Purple will reside in the newly constructed Terascale Simulation Facility (TSF). The TSF opened in July 2004 with a ribbon-cutting ceremony attended by then-Secretary of Energy Spencer Abraham. The facility encompasses approximately 253,000 square feet, including 48,000 square feet of raised computer floor for the high levels of power and cooling. It also includes an Advanced Simulation Laboratory for the development of data assessment hardware and software to analyze extremely large data sets. In early 2005, personnel began to move into the building, which is designed to house approximately 288 staff in both secure and open work areas.

Secretary of Energy Spencer Abraham autographs a panel cover of BlueGene/L during the opening of the Terascale Simulation Facility.

Reducing the WMD Threat



Reducing the WMD Threat

Reducing the threat posed by the proliferation, terrorist acquisition, or use of weapons of mass destruction (WMD) is an essential and enduring national security mission. Lawrence Livermore provides advanced technology, integrated analysis, unique expertise, and operational capabilities to assist the U.S. government in anticipating, preventing, detecting, and responding to the WMD activities of others.

Although the world at large has only recently become concerned about the seriousness and extent of WMD proliferation and terrorism threats, Laboratory efforts aimed at addressing this national security challenge began decades ago. Programs to assess the Soviet and Chinese nuclear weapons programs began in the mid-1960s. The 1970s saw the first detailed conflict simulation tools and atmospheric dispersion models. The science and technology that led to the Human Genome Project, the development of nucleic-acid signatures, and rapid, portable biodetectors have their roots in Livermore's biomedical program, which started in the early 1960s.

A distinguishing feature of Livermore's threat reduction work is its integrated, end-to-end approach. The full spectrum of threats is addressed—from preventing proliferation at its source, to detecting proliferant activities and identifying ways to counter those efforts, to responding to the threatened or actual use of WMD, to understanding the WMD capabilities and intentions of adversaries.

In response to the terrorist attacks of September 11, 2001, and the subsequent establishment of the Department of Homeland Security (DHS), Livermore is adapting technologies and analytical and operational capabilities developed for nonproliferation and counterterrorism to the specific needs of homeland security. Researchers are also developing tools and technologies to meet current Department of Defense needs and to assist in the broader defense transformation effort.

International Nonproliferation Activities

With support from U.S. government sponsors, Lawrence Livermore participates in numerous international cooperative activities aimed at preventing proliferation at the source. Foremost among them is the Material Protection, Control, and Accounting (MPC&A) Program, which is helping Russia enhance the security of vast quantities of Soviet-era nuclear material that could be used in a weapon. Livermore is unique among U.S. participants for its work with the Russian nuclear navy. Four nuclear weapons storage sites in the Kamchatka region are receiving comprehensive upgrades: two sites were completed in 2004, a third site is on track to be completed in 2005, and the fourth is scheduled for completion in 2006.

The National Nuclear Security Administration (NNSA) recently initiated the Global Radiological Threat Reduction Program, with the goal of keeping radiological materials out of the hands of terrorists who might want to detonate dirty bombs or perpetrate other forms of radiological terrorism. As with the MPC&A Program, the Laboratory is a key contributor to this effort, working with the Russian Ministry of Defense on the removal and storage of radioisotopic thermoelectric generators (RTGs) in the Russian Far East. Radioactive strontium-90 in the RTGs is used to power various operations in remote locations. The RTGs will be replaced with power sources (such as solar) that are not attractive to terrorists.

Livermore is helping the Russian nuclear navy protect its weapons-usable nuclear material.

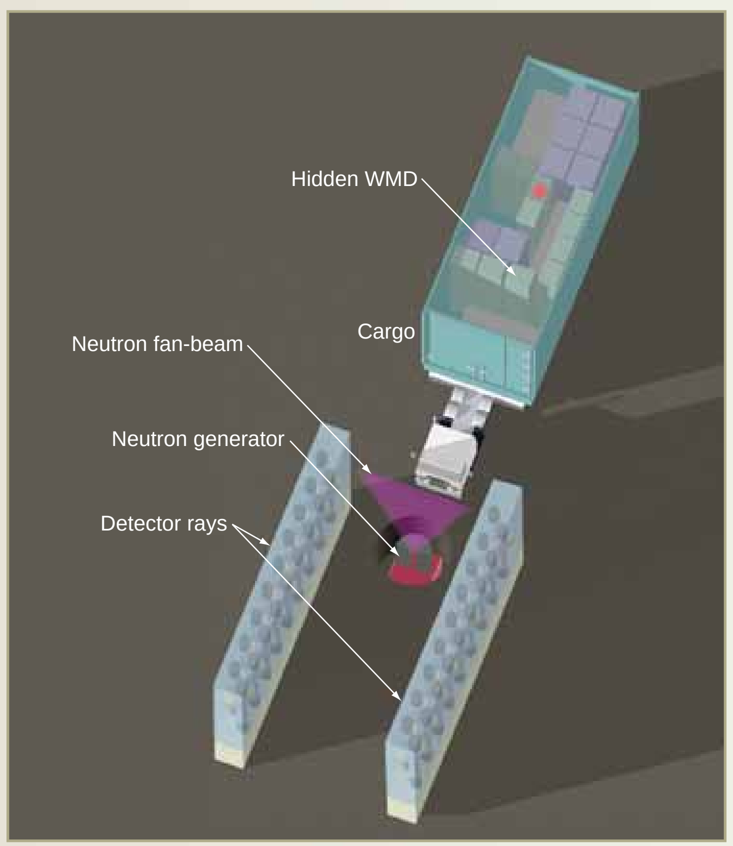
In December 2003, Libya renounced its WMD programs, including a clandestine nuclear weapons program. The Laboratory supported U.S. government efforts to examine, package, and ship thousands of tons of nuclear-related items out of Libya and provided policy, logistics, and intelligence support in Libya and at Department of Energy (DOE) headquarters. Laboratory experts were members of teams that removed critical material and equipment from Libya, transported it to the U.S., and examined it to characterize its past uses. One of Livermore's senior intelligence analysts participated in the joint U.S.–United Kingdom team that traveled to Libya to clarify open issues and establish a basis for confidence in Libya's nuclear declarations.

Radioisotopic thermonuclear generators are being replaced with power sources that are not attractive to terrorists.

Other international activities are aimed at helping to defuse the tensions that destabilize regions and motivate countries to acquire WMD. For example, Kyrgyzstan, Uzbekistan, and Tajikistan inherited a serious radioactive legacy from the Soviet Union in the form of uranium mine tailings that threaten to contaminate one of the region's main water sources and its prime agricultural resource. This region is historically a politically unstable area. Over the past several years, Livermore experts have helped to sponsor workshops to assess the environmental situation, collaborated with regional experts to propose possible ways to secure the mine tailings, and worked with major international donors to execute those plans. One achievement of this cooperative approach was its adoption by the regional and international community and its application to other Soviet uranium legacy issues in Central Asia.

Countering the Nuclear Threat

The radiation properties of nuclear materials, particularly highly enriched uranium (HEU), make detection technically difficult. Laboratory scientists are pursuing a number of projects to devise improved detector materials and instruments. Of particular note is a concept under study for detecting HEU inside cargo containers. The key is a high-energy gamma signature unique to HEU. Experiments conducted this past year at Lawrence Berkeley National Laboratory's 88-inch cyclotron and at Livermore verified this signature and its predicted characteristics. These experiments also confirmed the feasibility of detecting the signature at a moderate distance (3 meters) from a standard cargo container. Researchers are in the process of building a prototype system to test the detection concept under realistic operational conditions.



Detecting highly enriched uranium in a cargo container.

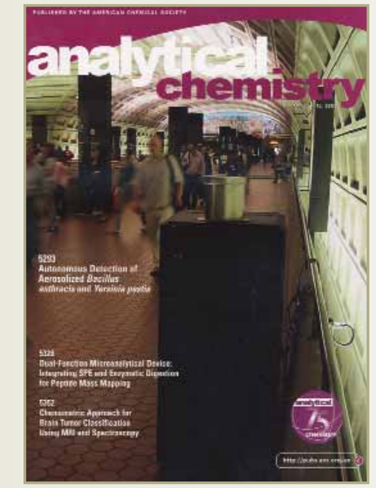
Lawrence Livermore also commercialized the technology for the RadScout detector. This portable instrument uses a high-purity germanium detector that is electromechanically cooled, eliminating the need for bulky liquid nitrogen cooling of the germanium detector crystal. With this instrument, field inspectors—such as Coast Guard or Customs officials—can detect a radioactive material and identify its isotopic content, enabling them to discriminate such innocuous sources as medical isotopes from legitimate concerns.

The instrument also offers "reachback" capabilities, whereby data collected in the field can be transmitted to technical experts at Lawrence Livermore and elsewhere for interpretation. The commercial version of this technology was first shipped to vendors in March 2004 as the ORTEC Detective by Advanced Measurement Technology, of Oak Ridge, Tennessee (see p. 44).

With initial funding from NNSA and ongoing support from DHS, Laboratory researchers have also developed RadNet, a radiation detection system built into a cellular telephone/personal digital assistant package. Individual units of this high-resolution, low-power device can replace both "radiation pagers" and "radioisotope identifiers" to provide a less expensive, easier to use, and higher performance instrument. Signals from all the units, including those connected to larger detection systems already deployed, are continuously combined to act as one large detection network blanketing an entire region. RadNet promises a dramatic improvement in the ability to detect, identify, locate, and respond to nuclear threats throughout the nation.

RadNet radiation detector.

2004 Annual Report



The Autonomous Pathogen Detection System, deployed in a Washington, D.C., Metro station, made science news.

A mass spectrometer is used to identify proteins in blood serum. These proteins are produced in the presence of pathogens.

Defending against Bioterrorism

Lawrence Livermore is one of the nation's leaders in the fight against biological terrorism and is a major participant in the DHS multilaboratory Chemical and Biological Countermeasures Program. Laboratory experts continue to provide technical support to BioWatch (the national system for detecting a large-scale bioattack against key U.S. cities), furnishing supplementary detection and analytical capabilities as well as on-call subject matter experts in the event of anomalous detections.

Researchers are also developing upgrades to BioWatch. For example, the the Autonomous Pathogen Detection System (APDS) was demonstrated in live-agent testing at Dugway Proving Ground and has been deployed in the Albuquerque airport, the Washington, D.C., Metro, a Bay Area Rapid Transit station in San Francisco, and in New York City. APDS can operate in such venues for more than a week without human intervention. For the longer term, the Laboratory is developing a new detection strategy, called the Bio-Briefcase, with the potential to be smaller, cheaper, more robust to changing back-grounds, and more highly multiplexed than APDS.

Current biodetection strategies assume that researchers and clinicians know what pathogens to look for. However, as the 2003 SARS outbreak demonstrated, this approach is not effective against unknown threats, either new, naturally occurring diseases or deliberately manipulated pathogens. This is the rationale behind a strategic initiative in "pathomics." Livermore researchers have developed an experimental strategy to see if they can generate unique biosignatures to identify presymptomatic infection, discriminate bacterial from viral infection, identify commonly occurring pathogens versus biothreats, and distinguish between different biothreat pathogens. Early results are encouraging. For example, this past year, an experiment exposed laboratory mice to the cowpox virus. They were then monitored to determine how early a developing infection could be detected based on molecular markers. Initial analyses indicated that infection can be clearly distinguished at day 8 and possibly as early as day 1 following exposure to the virus.

Pathomics is one of the thrust areas of the recently established BioSecurity and Nanosciences Laboratory (BSNL). BSNL scientists are discovering new methods to detect, identify, image, and understand such biological pathogens as anthrax, plague, smallpox, flu, tetanus, and botulinum toxin. They are also examining the function of proteins and proteins' response to bioagents.

Other research is under way to uncover the genetic basis for a disease's infectivity and virulence. An examination of bubonic plague—whose bacterium is perhaps the most infectious in humans—has revealed that plague's virulence may be caused by the inactivation of several hundred genes as the bacterium evolved over time.

By comparing the genome of the plague bacterium, *Yersinia pestis*, with its far less deadly cousin, *Y. pseudotuberculosis*, the team found that several genes in *Y. pestis* are not present in its relative.

In September 2004, the Laboratory opened the Biodefense Knowledge Center (BKC) for DHS. The center's goal is to provide in-depth analysis of biodefense issues that integrate disparate sources of information. BKC researchers are also developing information fusing and analysis tools and architectures to enable real-time assessment, tactical and strategic interpretation of biothreat data, and information processing in response to queries from critical user groups. BKC is a collaboration of the Lawrence Livermore, Sandia, Oak Ridge, and Pacific Northwest national laboratories and Science Applications International Corporation. Since its inception, BKC has responded to a variety of assessment requests, including one regarding a reported foot-and-mouth disease outbreak in Pakistan.

Department of Homeland Security undersecretary for science and technology Charles McQueary (left) dedicated the Biodefense Knowledge Center.

Emergency Planning and Response

Over the past several years, the Laboratory has taken on increased roles in emergency response planning and operations. These activities combine valuable first-hand experience with the needs of emergency responders to guide development of new technologies.

The National Atmospheric Release Advisory Center (NARAC), located at Lawrence Livermore, is the premier capability in the U.S. for real-time assessments of the transport and dispersion of hazardous materials released into the atmosphere. NARAC can model the behavior of radiological, chemical, biological, and natural materials on global, regional, or local scales. In April 2004, NARAC was designated by DHS as the primary interim provider for the Interagency Modeling and Atmospheric Assessment Center (IMAAC). IMAAC consolidates and integrates all federal efforts to model airborne releases into one emergency response organization for homeland security. This past year, NARAC/IMAAC supported numerous national security special events—the G8 Summit, Ronald Reagan's funeral, the Democratic and Republican national conventions—as well as real-world interagency responses. NARAC also participated in several national exercises in which NARAC predictions were the primary modeling products used to assess the consequences of airborne exposures.

The National Atmospheric Release Advisory Center is the provider for the DHS Interagency Modeling and Atmospheric Assessment Center.

The Nuclear Assessment Program (NAP) continues to be a cornerstone of the U.S. defense against nuclear threats and for countering nuclear smuggling. Because threats involving weapons other than nuclear are increasing, NAP has expanded its scope to include chemical and biological threat assessments and adversary studies as well. This group of analysts works closely with both the U.S. intelligence community and the national incident response community.

Lawrence Livermore is a member of DOE's nuclear incident response teams, including the Radiological Assistance Program (for assisting local agencies), Accident Response Group (ARG, for U.S. nuclear weapon accidents), Joint Technical Operations Team (for advanced capabilities to render safe a nuclear device), Triage (for incident support), and Attribution (for determining the origin of a nuclear device). In 2004, the Laboratory participated in numerous training exercises and alerts, including two State of California multi-agency WMD exercises and a no-notice ARG drill.

An exercise for a nuclear incident response team.

Support to Activities in Iraq

Lawrence Livermore provides multifaceted support to the Department of Defense in such areas as counterproliferation, force protection, and missile defense. During 2004, much of this support was focused on assisting U.S. efforts in Iraq.

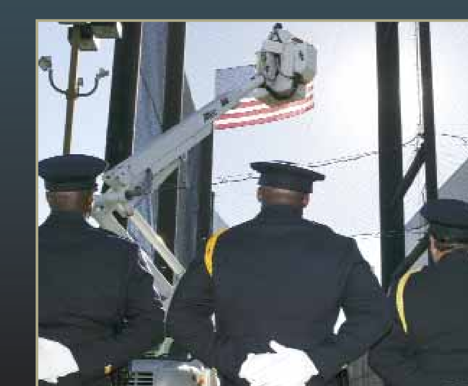
Livermore's Counterproliferation Analysis and Planning System (CAPS) provided 24/7 on-call support throughout Operation Iraqi Freedom. CAPS is a powerful modeling system for analyzing a country's WMD production processes and infrastructure and assessing interdiction operations and corresponding consequences. CAPS is the U.S. military's acknowledged standard for counterproliferation planning. To date, CAPS has completed assessments for more than 35 programs in 13 countries at 1,200 sites.

Livermore deployed four intelligence analysts to Iraq in the postwar period. They helped organize the WMD investigation and dismantlement effort, directed much of the nuclear weapons program-related work during that time, and helped write the principal draft for the Iraq Survey Group on the investigation into the Iraqi

Serving in the War on Terror

Laboratory researchers are noted for their technical contributions to the war on terror. Very special thanks go to another group of staff members—the more than 35 men and women of Lawrence Livermore who have served or are now serving in Afghanistan, Iraq, Kuwait, Guantanamo Bay, and elsewhere during the war. All have been called to active duty to serve in jobs ranging from the medical corps to infantry to legal support to intelligence. Most have served from 12 to 18 months, but one employee has been away over 3 years.

Dianne Buckhout (above) served in Iraq as an Air Force medic. A ceremony at the Laboratory (right) remembers the events of September 11, 2001.



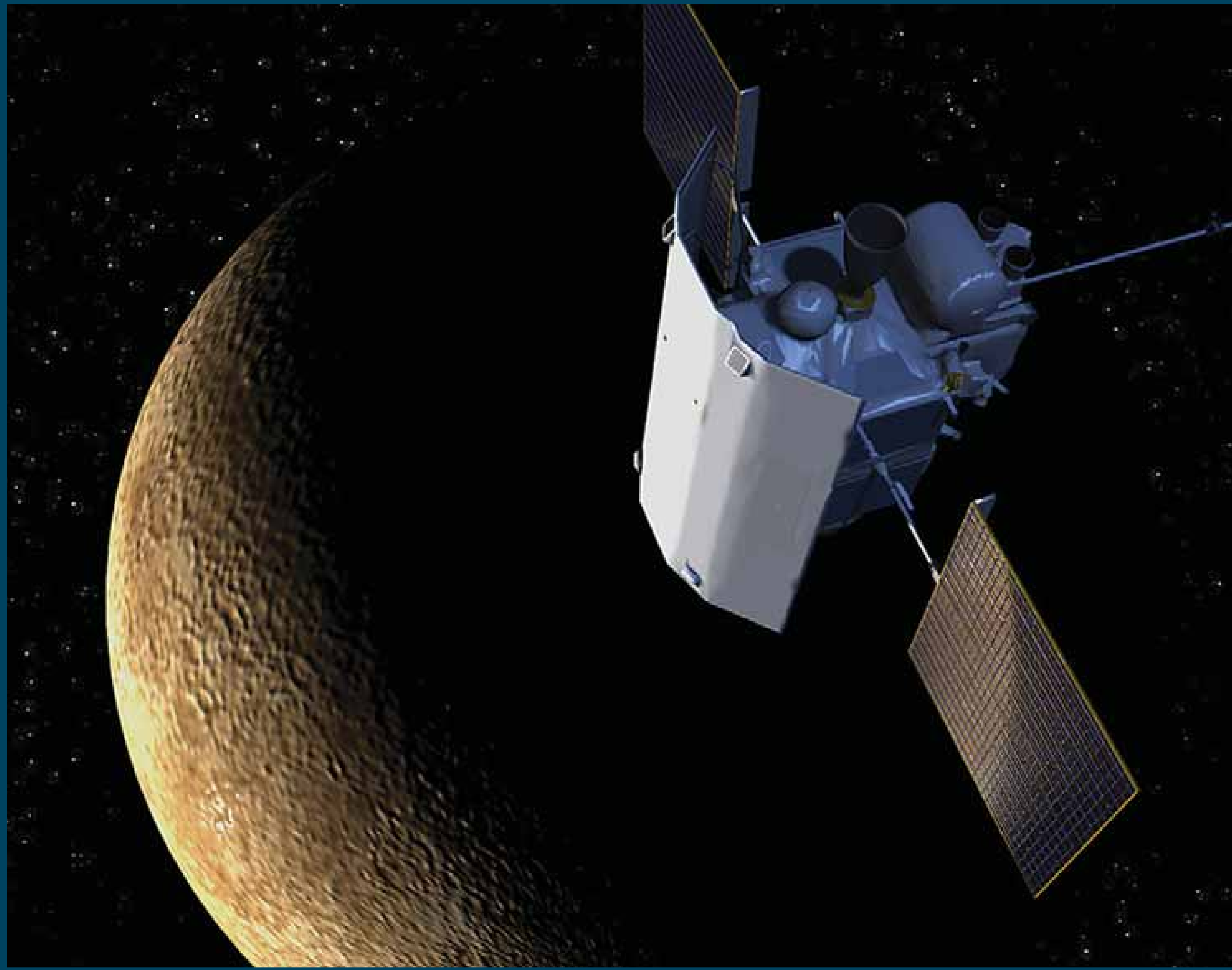
nuclear weapons program. Lawrence Livermore had a presence in Iraq throughout the most intensive investigations of the former regime's nuclear program by the Iraq Survey Group.

This past year, the Laboratory also provided technology to help protect U.S. forces in Iraq from roadside bombs, suicide bombers, and small-arms attacks. For example, an armor system designed for the Army is being used to convert 5-ton tactical vehicles to gun trucks that escort supply convoys and provide perimeter defense. Livermore began this project in January, tested the first prototype at the U.S. Army Aberdeen Test Center in March, and delivered the first armored gun truck kit in July. In Iraq, the newly armored trucks have been performing daily convoy escort duty with the Army's 7th and 457th Transportation Battalions out of Camp Anaconda in Balad.

This armor concept is saving lives. On November 30, 2004, a car bomb exploded next to a troop carrier outfitted with a lightweight version of the Livermore-designed armored box, and all of the soldiers in the attacked vehicle walked away essentially unharmed. In December, the Laboratory built and shipped 30 M923 gun truck kits, produced under Defense Advanced Research Projects Agency sponsorship, to four Army units in Iraq and Kuwait. The success of this effort has opened the possibility for developing new versions of the technology and other force protection concepts for U.S. soldiers in the field.

A truck protected by Livermore's armor system incurred relatively little damage from a car bombing in Iraq. Troops inside walked away essentially unharmed.

Meeting Enduring National Needs



Meeting Enduring National Needs

As part of its overarching national security mission, the Department of Energy (DOE) pursues research and development in areas of enduring importance to the nation. DOE mission priorities in energy and environment, bioscience, fundamental science, and applied technology are supported by Laboratory scientists and engineers. Livermore seeks challenges that reinforce its national security mission and have the potential for high-payoff results.

Long-term research is needed to provide the nation with abundant, reliable energy as well as a clean environment. Livermore's energy and environmental programs contribute to the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and to reducing risks to the environment.

Bioscience research at Livermore enhances the nation's health and security. Projects in genetics, molecular biology, computational biology, biotechnology, and health care research leverage the Laboratory's physical science, computing, and engineering capabilities. Research is directed at understanding the causes and mechanisms of ill health, developing biodefense capabilities, improving disease prevention, and lowering health care costs.

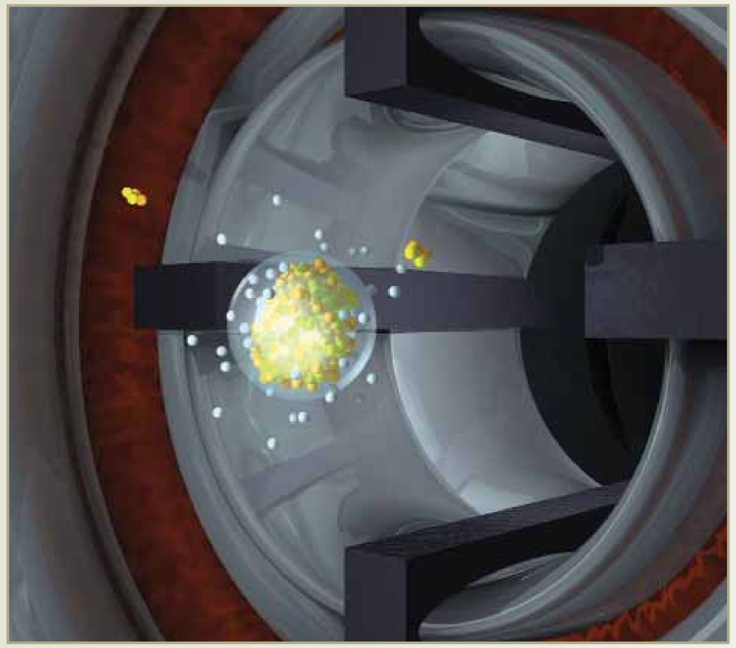
Livermore also pursues initiatives in fundamental science and applied technology that reinforce expertise needed for the Laboratory's national security mission. Many projects, sponsored by DOE's Office of Science and other customers, take advantage of the unique research capabilities and facilities at Livermore. Other work, supported by Laboratory Directed Research and Development funding, extends the Laboratory's capabilities in anticipation of new mission requirements.

Two Additions to the Periodic Table

A team that included Lawrence Livermore scientists discovered two new superheavy elements, 113 and 115, in experiments in Dubna, Russia. Researchers from Russia's Joint Institute for Nuclear Research (JINR) and Livermore used the JINR U400 cyclotron to slam an intense beam of calcium-48 nuclei into americium-243 targets. In the gas-filled separator beyond the cyclotron, four atoms of element 115 were created, which decayed to produce four atoms of element 113. These findings were published in the February 1 issue of *Physical Review C*.

The team observed three similar decay chains consisting of five consecutive alpha decays. These events combined took less than 30 seconds and terminated in a spontaneous fission of an element-105 isotope with a half-life of 16 hours. A 16-hour half-life is considered exceptionally long for any of the unstable elements.

Associates at JINR's ion-source group produced the intense calcium beams, while Livermore supplied the americium target material. Elements 113 and 115 join two other elements that Lawrence Livermore and Dubna scientists discovered in the late 1990s, elements 114 and 116.



Alpha decay of a newly created atom of element 115 produces element 113, also a new element.

Breakthroughs from Quantum Calculations

Quantum molecular dynamics calculations are making major contributions to the science of materials ubiquitous in our environment. The October 7 cover of *Nature* reported a new melt curve of hydrogen at extremely high pressures predicted by Livermore scientists using the ab initio molecular dynamics code GP. This new curve presents the melting point of hydrogen at pressures from 50 to 200 gigapascals with temperatures from 600 to 1,000 kelvins. These findings led the team to propose new experimental measurements that could help verify the existence of a maximum melting temperature and the transformation of solid molecular hydrogen into a metallic liquid at pressures close to 400 gigapascals. Melting point maximums are unusual but are also found in water and graphite.

Livermore's terascale computers have revealed details of the reactive states and faster relaxation of molecules at the interface of water and air in the first-ever ab initio simulations of a stable liquid–air interface. The data analysis shows a faster relaxation of water molecules at the interface and reveals that the surface contains far more reactive states than bulk water does. The models reproduced surface phenomena of water that had been observed experimentally by a group at the University of California at Berkeley. Results appeared in *Science* on January 30. These simulations constitute an important step in the use of terascale computers to understand the behavior of water in complex environments.

Research on hydrogen made the cover of Nature.

Thunder Rumbles Online

A new unclassified supercomputer, the Linux-based cluster Thunder, made an impressive debut at number 2 on the prestigious Top500 list of the world's fastest computers when it was installed in June. It currently sits at number 5 on the list.

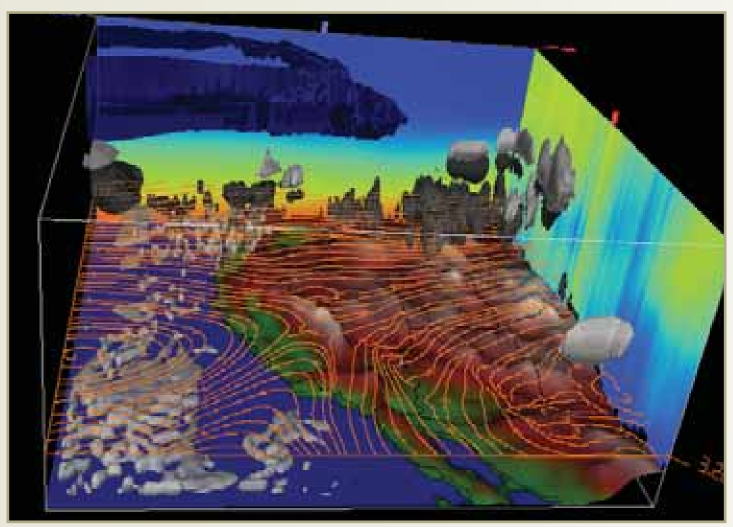
Thunder augments Livermore's Multiprogrammatic Capability Resource (MCR), which began running late in 2002. MCR, with a top speed of 11.2 trillion operations per second (teraops), and Thunder together offer Livermore scientists and collaborators access to an unparalleled set of resources for simulation science. Simulations run on Thunder have already resulted in scientific breakthroughs. One example is climate modeling that uses the regional climate model MM5. Thunder holds the record for the fastest MM5 climate model of a simulated day.

Thunder, built from 4,096 Intel Itanium 2 processors, has a peak speed of 23 teraops. It runs on an open-source software environment developed and maintained at the Laboratory called CHAOS (Clustered High Availability Operating System). Thunder was designed primarily for scientific research in such areas as materials science, biology, structural mechanics, cosmology, and energy and environment, including seismology and atmospheric and climate studies. Thunder also runs unclassified simulations for stockpile stewardship.

New Telescope Probes Hard X-Ray Sources

Livermore participated in an international collaboration to build the High Energy Focusing Telescope (HEFT), whose optics will allow scientists to observe hard x rays emitted by some of the most energetic objects known, including supermassive black holes, stars, and pulsars. HEFT, sponsored by the National Aeronautics and Space Administration (NASA), will focus on Cassiopeia A, a supernova remnant. Measuring x rays from Earth's surface is impossible because they are mostly absorbed by Earth's atmosphere. HEFT was launched into Earth's atmosphere by balloon in late fall 2004.

This project exploits Livermore expertise in the design and construction of hard x-ray focusing optics. Nearly cylindrical mirrors are fabricated of multilayers in varying thicknesses to efficiently collect x rays over a wide range of angles and photon energies. The mirrors are combined with a solid-state cadmium–zinc–telluride pixel detector developed by the California Institute of Technology, a project collaborator. This focusing optics system offers a dramatic improvement in sensitivity and angular resolution over previous hard x-ray telescopes. Combining the expertise of the two organizations solves the problem of collecting and analyzing hard x rays from very weak sources in a tool that is expected to provide entirely new information about deep space.



An MM5 climate model run on Thunder.

Mirrors for the High Energy Focusing Telescope to probe hard x-ray sources.

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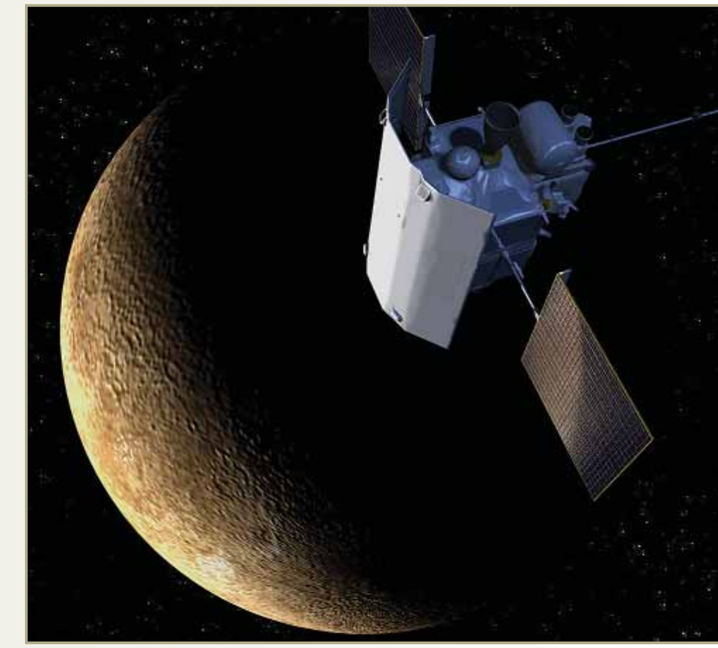
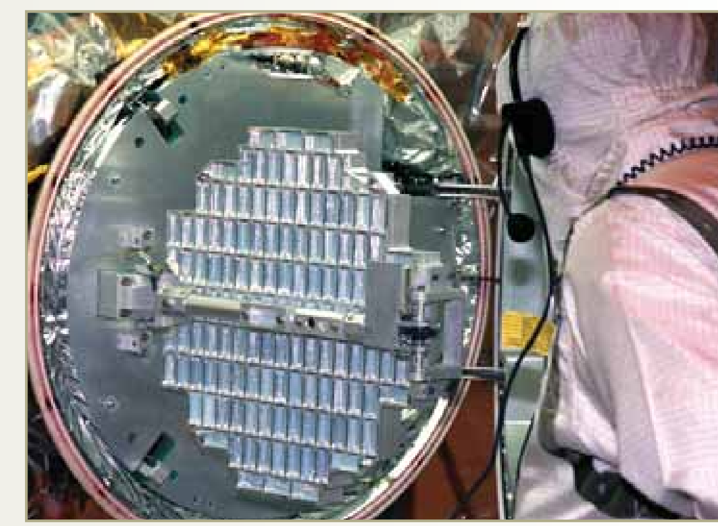
Astrophysics Research Goes to Mercury and Beyond

The Mercury MESSENGER spacecraft was launched in August 2004 and will conduct an in-depth study of Mercury in 2008 and 2009 flybys and during a yearlong orbit of the planet starting in March 2011. A rugged, high-resolution gamma detector, built by a Laboratory-led team, rides on MESSENGER, short for Mercury Surface, Space Environment, Geochemistry, and Ranger. The detector is mated with a miniature cryocooler and a multilayer thermal shield that protects it from intense heat due to Mercury's proximity to the Sun. As MESSENGER orbits the planet, it will use the detector to measure characteristic gamma-ray emissions from Mercury's crust as well as solar winds and cosmic rays.

Livermore is involved in other spacecraft travels as well. NASA launched the Stardust spacecraft in 1999. In January 2004, it flew by Comet Wild 2's nucleus and through a halo of gases and dust at the comet's head, collecting cometary dust particles. In 2006, the spacecraft will deliver less than 1 milligram of particles to Earth. In preparation for this cosmic gift, a team is perfecting ways to extract and analyze the tiny particles. The particles are being captured in a grid filled with silica-based aerogel developed earlier by Livermore scientists. The team has developed a miniscule wedge used in conjunction with focused ion-beam microscopy to cut particles out of the aerogel. Tiny sections will be examined using a



Artist's rendering of the MESSENGER spacecraft over Mercury.



The grid for collecting dust particles from Comet Wild 2.

scanning transmission electron microscope, a nano secondary-ion mass spectrometer, and a synchrotron infrared microscope.

Laser guide star adaptive optics created by Livermore scientists were used to observe that distant larger stars form in flattened accretion disks just like the Sun. Observations at the University of California's (UC's) Lick Observatory revealed that some relatively young yet massive Herbig Ae/Be stars contain biconical nebulae, polarized jets, and circumstellar disks. Less massive stars, including the Sun, are believed to be formed in a swirling spherical cloud that collapses into a disk. This research appeared in the February 27 issue of *Science*.

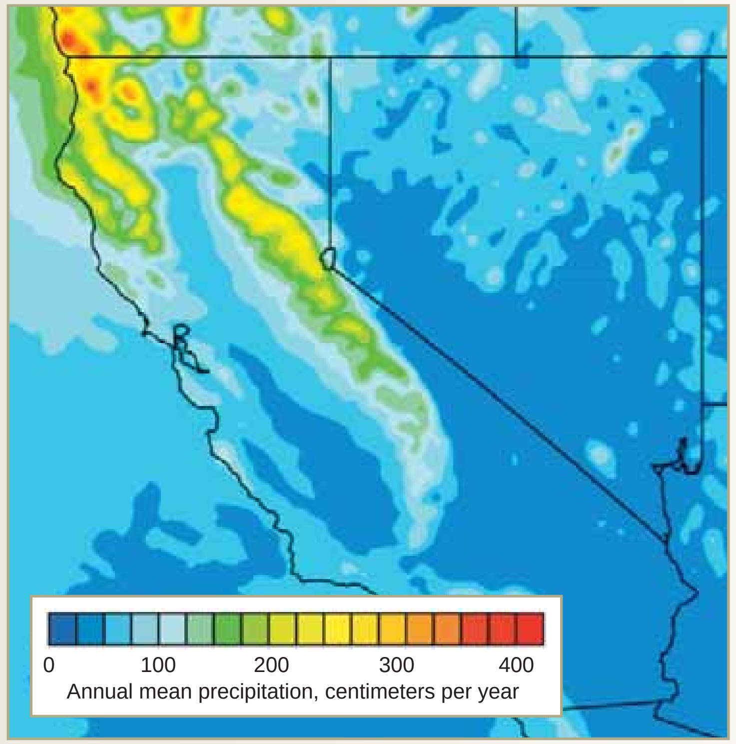
The February 20 issue of *Astrophysical Journal Letters* reported on the discovery that gamma-ray bursts are important sources of several common elements. Livermore participated in a team that found that each gamma-ray burst expels about half a solar mass of readily visible radio-active nickel. After a few months, this radioactive nickel decays to iron. Calculations show that gamma-ray bursts also produce enormous quantities of zinc, titanium, calcium, and scandium. Although gamma-ray bursts are rare, these events may account for as much of some elements as all other stellar explosions combined.

Understanding Global Climate Change

Livermore's efforts in the science of climate change extend from the broadest global view to the smallest possible regional scale. For the upcoming assess-ments by the Intergovern-mental Panel on Climate Change (IPCC), Livermore scientists have implemented the capability to house and distribute the entire inter-national dataset of climate model simulations being completed for the 2007 IPCC report. All simulation results will be distributed via the DOE Earth System Grid Web portal, giving unprecedented access to climate information. For a better understanding of climate change on the regional level, where policy decisions have the most effect, Livermore has used its supercomputing platforms to drive the resolution of its climate modeling down to 9 kilometers.

One such fine-scale model indicates that an increase in global climate temperatures is already affecting water availability in California and is likely to worsen as the century progresses. Climate and hydrologic models show that if the global warming trend continues, there will be less snow, more rain, less available water, and an increased chance of floods in California. Observations of earlier snow melt and a decrease in late spring and summer river flow rates show that California is getting warmer.

Other models have been put to work to analyze data collected by aircraft, satellites, and ground-based instruments during NASA's 2002 Cirrus Regional Study of Tropical Anvils and Cirrus Layers-Florida Area Cirrus Experiment (CRYSTAL-FACE). In work published in the April 9 issue of *Science*, a team simulated how both ozone and hydrogen chloride in the stratosphere—where 90 percent of the world's ozone is located—travel downward and into the upper troposphere. Simulation results and measurements by CRYSTAL-FACE validate a new technique that uses hydrogen chloride measurements to better understand the contribution of the stratosphere to upper tropospheric ozone concentrations.



This climate model of rainfall in California has an extremely fine resolution of 9 kilometers.

Helping Ensure Clean, Reliable Water Supplies

Livermore has undertaken an ambitious three-year Water Initiative to develop tools that will help water resource managers make the best decisions about California's water supply infrastructure, protection, and treatment. This multifaceted project exploits long-standing Laboratory strengths—providing better predictive climate models, improving the scientific understanding of water contamination, and developing more cost-effective technologies for purifying water.

The goal of the modeling effort is to project future changes in the hydrologic cycle in California and determine how these changes will affect the availability of freshwater, as described above. Simulations of future water supplies run on Livermore's supercomputers are linking a sequence of models that start with global climate models and end with surface hydrology models. Initial results have led to endorsements by federal, state, and local agencies for a center to address long-term water-supply predictions for California.

Work on water contamination examines the natural processes that control the movement and degradation of nitrates in groundwater, which may come from fertilized farmland, dairies, feedlots, and septic tanks. A team of experts in isotope hydrology, ground-water modeling, and molec-ular biology is studying

Claire Max Wins E. O. Lawrence Award

Claire Max, an astrophysicist at the Laboratory and a faculty member at the University of California at Santa Cruz, was one of seven winners of the Department of Energy's E. O. Lawrence Award for 2004. Max received the award in the physics category for her contributions to the theory of laser guide star adaptive optics and its application in ground-based astronomy. Adaptive optics correct telescopic images for the blurring caused by light passing through the atmosphere.

Max is a member of the Laboratory's Institute for Geophysics and Planetary Physics and was its founding director in the early 1980s. She is one of the coinventors of the sodium laser guide star and is a leader in implementing these new artificial guide stars at astronomical observatories. Laser guide stars enhance the clarity of ground-based observations by a factor of 50 or more, making them comparable to space-based telescopes. In addition to revealing the flattened accretion disks described above, this new technology has given scientists infrared images and spectra of storms on Neptune, hydrocarbon oceans and ice continents on Titan, and black holes in the core of the Milky Way.

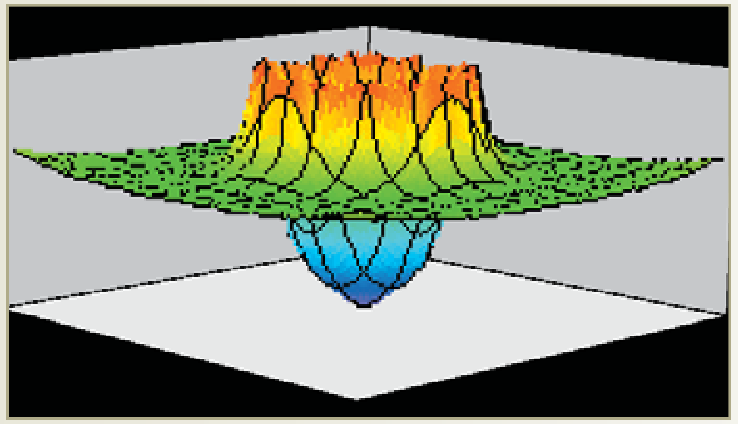
microbial control of nitrate degradation at the laboratory scale; at the farm scale, using a dairy farm in California's Central Valley; and at the larger, water-basin scale, in Santa Clara County's Llagas Basin.

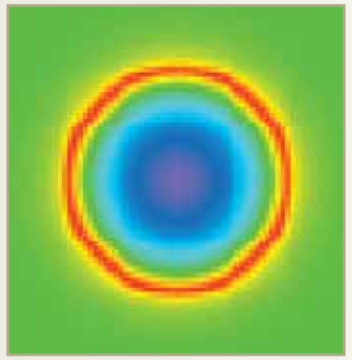
Many water supply wells that have been closed because of nitrate or other contamination could be reopened if the water is treated. An effort to develop a cost-effective, energy-efficient membrane for water treatment uses a new "smart," or selective, membrane designed to remove only specific contaminants. Quantum calculations have aided the design of the membrane's pore size, surface charge, and applied electrical field, so that the membrane removes only specified contaminants.

Progress in Magnetic Fusion Energy

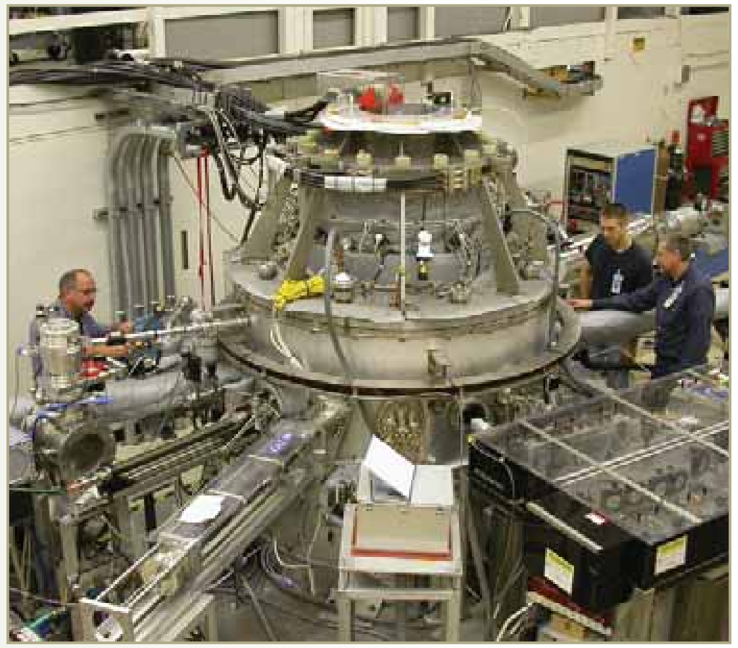
Laboratory researchers are advancing magnetic fusion energy science through computational and experimental work performed primarily for DOE's Office of Science. Livermore collaborates in experiments using the DIII-D Tokamak at General Atomics in San Diego. Results will have important implications for the performance of the International Thermonuclear Experimental Reactor, a major international project with significant U.S. participation.

Livermore is also examining an alternative to the tokamak concept at its Sustained Spheromak Physics Experiment, which may lead to lower-cost fusion reactors because of the spheromak's compact size and reduced complexity. Because of the difficulty of diagnosing experiments without disturbing the plasma, computer simulations are aiding the quest to understand what is happening inside the spheromak's hot plasma. Laboratory scientists and collaborators at the University of Wisconsin are using supercomputers at DOE's National Energy Research Scientific Computing Center at Berkeley. The results, which were presented in an invited talk at the 2004 annual meeting of the American Physical Society's Division of Plasma Physics, confirm how careful tuning of the current pulses can improve plasma performance and achieve higher temperatures.





Quantum calculations of the electrostatic charge around pores help design "smart" water purification membranes.



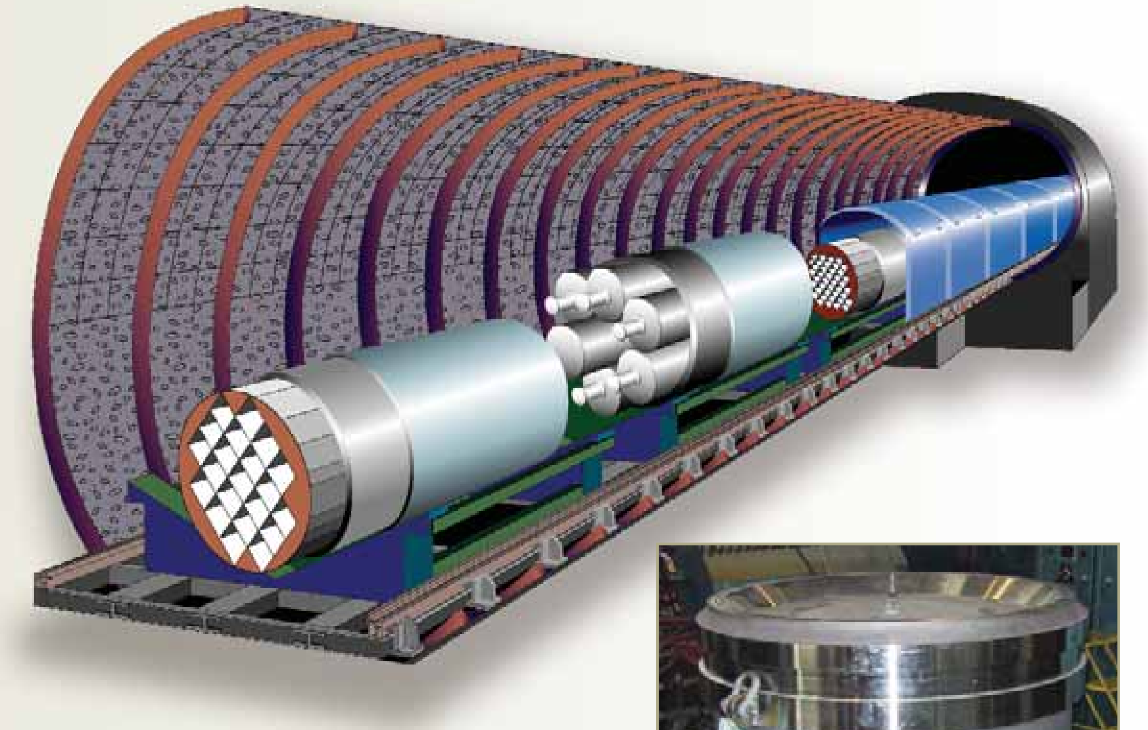
The vacuum vessel for the Sustained Spheromak Physics Experiment.

Testing and Modeling for a Nuclear Waste Repository

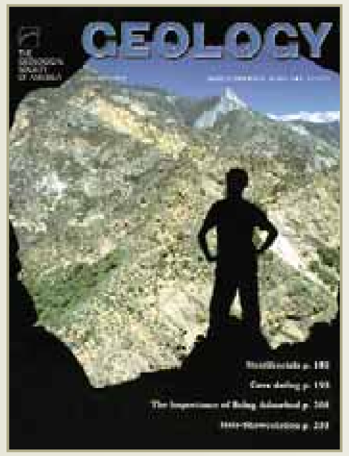
A team of Livermore researchers is testing and refining the design and materials for up to 12,000 nuclear waste packages as part of DOE's program to design, license, and build an underground nuclear waste repository in Yucca Mountain, Nevada. The repository would house more than 70,000 metric tons of spent nuclear fuel from civilian nuclear power plants and highly radioactive waste from defense-related activities at DOE facilities across the U.S.

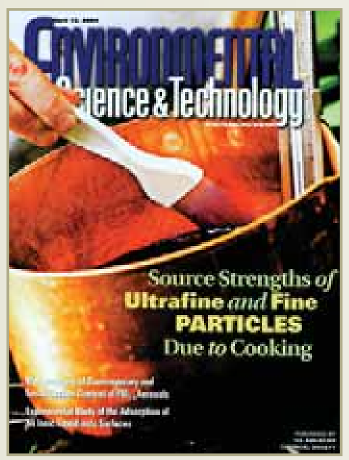
Applying the principle of defense in depth, the repository would incorporate multiple protective barriers, both natural and engineered. The engineered barriers include canisters to contain the waste packages and an overhanging drip shield of titanium. Livermore has been the longtime lead laboratory for the advanced materials science of the waste packages. Experiments at Livermore's Long-Term Corrosion Test Facility have helped to develop an understanding of corrosion rates and corrosion resistance of the waste packages in various environments. This work formed much of the basis for a successful review of the Yucca Mountain Project by the Nuclear Waste Technical Review Board in 2004.

Livermore has also been responsible for predicting the thermal, mechanical, hydrologic, and chemical processes that will occur deep underground at the Yucca Mountain site for a 10,000-year performance period. Livermore researchers have developed advanced geologic simulations to predict the long-term evolution of the environment in the tunnels, or drifts. The simulations will form the scientific basis for DOE's formal license application to proceed with construction of the Yucca Mountain repository, which will be submitted to the Nuclear Regulatory Commission.



Canisters (right) of nuclear waste will be stored in tunnels at Yucca Mountain, as shown above.





Discoveries at the Center for Accelerator Mass Spectrometry were cover news.

One Instrument, Many Rewards

Livermore's Center for Accelerator Mass Spectrometry (CAMS), home to the most versatile and productive AMS facility in the world, had its research featured on the cover of several publications in 2004. The March issue of *Geology* highlighted work that used cave sediments for cosmogenic dating, allowing a team to determine how erosion rates and seismic activity helped form the Sierra Nevada mountain range. In April, *Environmental Science & Technology* featured work to unlock the key to haze in the Yosemite Valley. A team collected air samples in Yosemite National Park over a three-month period and found that massive wildfires in the western U.S. likely contributed to periods of haze in Yosemite. This research is part of an ongoing project that is examining sources of haze in numerous other national parks and regions of the country. The September issue of *Meteoritics & Planetary Science* featured a project in which a nuclear microprobe was used to characterize interstellar dust particles as part of the Stardust project (see p. 25).

CAMS has close ties to the University of California (UC), in part because the UC Board of Regents invested in the spectrometer back in the 1980s in exchange for guaranteed access by students and staff from all UC campuses. An illustration of the close tie was the October appointment of the CAMS director to head the UC Toxic Substances Research and Teaching Program (TSRTP), headquartered at UC Davis. The TSRTP serves as a focal point for bringing together UC and national laboratory researchers for risk assessments on toxic substances. In the past, the TSRTP, at the request of the California Legislature, conducted research studies into the effects of methyl tertiary butyl ether (MTBE) that led to the state's decision to phase out the gasoline additive.

Genetics Advances on Many Fronts

The discovery of gene activity in what were thought to be "gene deserts," the sequencing of a microscopic ocean algae that mediates global warming, and the completion of sequencing for chromosomes 5, 16, and 19—these are just a few of the advances made in 2004 at the Joint Genome Institute (JGI) in Walnut Creek, California. Livermore's collaboration with Los Alamos and Lawrence Berkeley national laboratories at JGI continues to make major contributions to fields ranging from disease treatment to environmental remediation to agriculture. In March, JGI celebrated sequencing 2 billion bases in one month, an unprecedented level of DNA sequence generation. The completion of the DNA roadmap for chromosome 19 was especially poignant for Lawrence Livermore; the Laboratory began researching this most gene-rich of all the chromosomes in 1986.

Gene deserts are long stretches of DNA between genes that were once thought to have no biological function and were

A step in the DNA sequencing process at the Joint Genome Institute (JGI).

2004 Annual Report

dismissed as junk DNA. But research published in December in the online version of *Genome Research* shows that gene deserts are home to a surprisingly large fraction of the genome's noncoding regulatory elements. A computational comparison of the genomes of different species revealed that gene deserts fall into two categories: those that remain relatively stable throughout eons of evolution and those that undergo significant variation. It turns out to be these stable regions that are so rich in regulatory DNA. This information is important for researchers looking for mutations leading to diseases because it highlights large areas of the genome that are not likely to be involved in causing disease.

In April, representatives of a dozen laboratories gathered at JGI to chart the metabolic processes of a microbe, *Desulfovibrio desulfuricans* G20, which has a robust appetite for such toxic metals as uranium and chromium. DOE's interest in the microbe hinges on its ability to detoxify uranium. The uranium then is not as harmful to humans, insoluble in water, and immobilized in soil. In research similarly aimed at environmental remediation, JGI generated the first genetic instruction manual of the diatom *Thalassiosira pseudonana*, one of Earth's most prolific assimilators of carbon dioxide. This work, published in the October 1 issue of *Science*, helps scientists understand the role that this and other phytoplankton play in mediating global warming.

A three-way partnership of DOE, the U.S. Department of Agriculture, and the National Science Foundation funded DNA sequencing at JGI of two related deadly genomes, *Phytophthora sojae*, which causes root rot in soybeans, and *Phytophthora ramorum*, a pathogen that causes sudden death in oak trees. *Phytophthora sojae* caused more than $1 billion in damage to the 2003 soybean crop. With the DNA sequences in hand, researchers can now home in on genes related to disease transmission and virulence in both plant species.

At Livermore, the Laboratory has opened a Microarray Center to give scientists onsite access to the latest microarray equipment for analyzing DNA, proteins, and peptides. Microarrays, also known as biochips or gene chips, are a powerful new tool that researchers can use to quickly and efficiently determine which genes in a cell are active, or "expressed," under differing conditions. Livermore researchers in many fields will use this new center. Work is under way to study the plague bacterium and how a host organism's gene activity changes when it is infected. Other projects include developing rapid diagnostic techniques for biodetection and forensics and studying protein–protein and protein–DNA interactions with protein arrays.

DNA sequencing machines at JGI.

Thalassiosira pseudonana*, one of Earth's most prolific assimilators of carbon dioxide, may be important for remediating this greenhouse gas.*

Solving the Protein Structure Challenge

With the Human Genome Project complete, the next major biological challenge is to gain a better understanding of the proteins that are encoded by DNA's genes. The hemoglobin that carries oxygen, the enzymes and hormones that turn cells on and off, the antibodies that fight infection—all are proteins, and their shape and function are intimately related. Because disease can occur when a protein does not fold into its correct shape, knowing that shape is critical for designing therapeutic drugs. Alzheimer's disease is one example of about 20 diseases caused by protein misfolding.

Determining a protein's shape or structure by experimental methods is complicated and enormously time consuming. A consequence is that the structure of only a small percentage of proteins is known. For many years, researchers have sought to exploit computational tools to predict protein structure. Livermore was a major player in organizing the Critical Assessment of Techniques for Protein Structure Prediction (CASP), a biennial experiment that brings together groups of scientists from more than 20 countries to predict the structure of proteins. Results from the most recent round of predictions were reviewed at the CASP6 conference, held in December 2004 in Gaeta, Italy. Livermore continues to be a leader in protein structure prediction, forming the Protein Structure Prediction Center to develop software tools for streamlining the process. Livermore has also created a database of protein models that functions as both a search tool and a model evaluator.

Other Livermore researchers are examining protein folding one molecule at a time in the first-ever study of protein-folding kinetics on the single-molecule level. Scientists believe that the folding process sometimes becomes derailed because of increased temperatures, acidity, or other factors, which then causes disease. To gain a greater understanding of the folding process, a Livermore team working under the auspices of the BioSecurity and Nanosciences Laboratory, developed a microfluidic mixer in which protein and various chemicals can be combined. The team is monitoring protein-folding kinetics in millisecond snapshots, and new technology is being developed to allow observations of folding on a nanosecond time scale.

At left, the crystal structure of TM0919, one of the target proteins for CASP6. Center, a successful prediction (red) for TM0919 is compared with the crystal structure. At right, a less successful prediction for the same target protein.

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Laboratory Operations

Laboratory Operations

SAFE, SECURE, AND EFFICIENT OPERATIONS ARE AN INTEGRAL part of Livermore's research and development programs, and the Laboratory sets high standards in all aspects of its operations. Together, quality operations and scientific and technical excellence make possible Livermore's programmatic accomplishments and sustain public trust in the Laboratory.

Safety and security are the most important considerations in day-to-day operations. The Laboratory provides employees and neighboring communities with a safe and healthy environment in which to work and live. A personal commitment by all employees to the safety of their work—and of the individuals around them—is indicative of a deeply rooted safety culture. The Laboratory is continually improving systems in place to ensure that proper safety practices are learned and followed by all. Security, which is also the responsibility of every employee, requires constant vigilance. Nuclear materials, sensitive information, and other valuable assets at Livermore must be protected against new and evolving threats. The Laboratory also seeks to continually improve business processes and systems, infrastructure management, and administrative functions to be best in class among high-technology research organizations.

Business as usual is not good enough—the Laboratory is committed to continual process improvement in all facets of its work. The demand is greater than ever before to improve efficiency and cut costs while complying with an increasingly complex regulatory environment. A strategic, institutional view guides priorities regarding where and how to improve work processes. A major challenge is to appropriately measure performance to gauge success and provide quality assurance to Laboratory and contract managers, government officials, and the general public.

Safety Is Paramount

The Laboratory sets high expectations for the environmental, health, and safety performance of employees. Livermore's Integrated Safety Management (ISM) system provides a framework through which safety procedures and practices are continually improved. Most importantly, a focus on safety, a commitment at all levels of management, and sound implementation of ISM by each individual are critical to success.

The National Ignition Facility (NIF), which is by far the Laboratory's largest-ever construction project, has achieved a remarkable safety record and sets an example of excellence in safety. With the slogan "The Goal is Zero," the NIF project has developed a pervasive safety culture with buy-in from each individual and effective implementation of the basic steps of ISM. In December 2004, the NIF project celebrated its fourth year without a lost work day from an on-the-job injury. NIF personnel have worked over four million consecutive safe hours.

NIF's Total Recordable Rate (an industry standard benchmark that measures the percentage of injuries compared to the size of the workforce) stands at 0.8, which is considered to be world class. According to federal government data, the incident rate of NIF-category work-related injuries and illnesses is 8.8 nationally.

In 2004, Plant Engineering, which provides all facilities and site infrastructure services at the Laboratory, instituted a program to improve its safety culture. Better communication, pretask planning, increased training, and greater involvement by supervisors and managers are some core elements of the program. To date, Plant Engineering crafts personnel have worked more than 1.4 million shop hours without a lost work day.

Strengthening Security

Upgrades by the Laboratory, security reviews by the Department of Energy (DOE), and awards received in 2004 highlight the importance of ensuring the protection of sensitive information, nuclear materials, and other valuable assets at Livermore. An extensive security apparatus is in place, and improvements are continually made to address new threats and concerns.

An important security enhancement since September 11, 2001, is the change to controlled access of a 1-mile stretch of East Avenue that runs between Lawrence Livermore and Sandia national laboratories. In 2004, this project was completed with the addition of the Delivery Vehicle Inspection Station to process truck traffic to both laboratories. The facility includes two all-weather, high-bay inspection lanes for full-sized trucks, state-of-the-art surveillance and detection equipment, and accommodations for explosives-sniffing dogs.

Linton Brooks, Administrator of the National Nuclear Security Administration (NNSA), came to the Laboratory in October to review Livermore's security operations. His one-day visit was part of a complex-wide tour of NNSA security facilities. After meetings with senior Laboratory and DOE

The National Ignition Facility celebrates achieving four million safe work hours.

Members of the press witness an explosives-sniffing dog at work at the new Delivery Vehicle Inspection Station.

Site Office managers, Brooks toured Livermore's special nuclear materials facilities (the Superblock) and witnessed Protective Force operations and training demonstrations.

Earlier in the year, DOE's Office of Safeguards and Security Evaluations and Office of Cyber Security and Special Reviews conducted a special review at Livermore. The assessments included examination of Protective Force management, the lock and key control program, security incident reporting, and classified cyber security. The two areas that were formally rated—cyber security and Protective Force—received an "effective performance" grade, the highest rating possible. The review stated that Livermore's locks and keys program, which was revamped after incidents in 2003, is "best in complex." The management of classified removable electronic media (CREM) was also subjected to review in 2004. In July, DOE ordered a standdown on CREM to conduct a complete inventory and institute new CREM procedures. Livermore's standdown revealed no fundamental security risks but did identify opportunities for administrative improvements.

Livermore's Security Awareness for Employees (SAFE) Program for counter-intelligence awareness underwent an intensive review by DOE's Office of Counter-intelligence in March. The inspectors rated SAFE in 12 areas, including management, operations, and liaison with other Laboratory organizations. The program earned the first "excellent" rating ever garnered by a DOE/NNSA counter-intelligence office in such a thorough inspection. The Laboratory also received third-place honors in the 2004 National Operational Security awards out of 81 nominees submitted from a range of government agencies.

NNSA Administrator Linton Brooks (center) meets with Protective Force officers.

Responsible Environmental Management

After more than a dozen years of assembling and analyzing Laboratory environmental data, the Agency for Toxic Substances and Disease Registry (ATSDR) completed its formal Public Health Assessments of the Laboratory's two sites in 2004. The documents state that there are no apparent public health hazards from past or ongoing operations and environmental releases from the Livermore main site or Site 300. The agency also said public health impacts from future operations were not likely. ATSDR is part of the Centers for Disease Control and Prevention of the U.S. Department of Health and Human Services. This agency is responsible for assessing public health impacts at DOE sites undergoing environmental restoration.

Cyber Warriors Recognized

For 15 years, the staff in the Computer Incident Advisory Capability (CIAC) at Livermore has matched wits with malicious denizens of cyberspace to protect DOE/NNSA computer users. CIAC is one of the two oldest computer response teams in the country and has earned wide recognition for its contributions to the information technology community. CIAC's list of clients has grown beyond DOE to encompass other federal agencies, including several incidents during which the team worked with the Federal Bureau of Investigation.

Cyber attacks are increasing in number, virulence, and sophistication. CIAC has countered by improving response time, strengthening relationships with customers, and developing preventive programs such as the Advanced Warning and Response system. Their efforts were rewarded in 2004 with a certificate of appreciation from the DOE Chief Information Officer, the program's sponsor.

In addition to maintaining safe and compliant operations, the Laboratory's environmental management efforts include remediation of groundwater contaminated many decades ago, hazardous and radioactive waste management from ongoing programs, and disposal of legacy waste. A major accomplishment in 2004 was the removal of 682 drums of transuranic (TRU) waste from the Laboratory site. This legacy TRU waste had accumulated during decades of weapons program activities. Working in a highly successful partnership with DOE, Livermore shipped this material to the Waste Isolation Pilot Plant near Carlsbad, New Mexico. The 18 shipments—with drums packed in special containers that weighed almost 15,000 pounds—began in October 2004 and concluded in January 2005. To meet stringent transportation and disposal requirements, Laboratory specialists worked with a DOE contractor over a 10-month period prior to shipping to carefully characterize the waste in each drum using radiography, gas chromatography, and gamma spectroscopy.

Legacy transuranic waste has been removed from the Laboratory.

New Facilities Transform the Laboratory

The Laboratory's skyline has been redefined with the construction of NIF—the world's largest laser in a building the size of a sports arena—and the Terascale Simulation Facility—which will house two of the world's most powerful computers (see pp. 8 and 12). But those are not the only construction projects reaching fruition. A ribbon-cutting ceremony in February 2004 marked the opening of the Laboratory's International Security Research Facility. The new two-story facility consolidates most of Livermore's intelligence-related work in a single building. Its 21st-century digital communications capabilities better connect Laboratory analysts with others in the intelligence community.

With funding from NNSA's Facilities and Infrastructure Recapitalization Program (FIRP) and Institutional General Plant Projects, the pilot FIRP Replacement Office Building Project was completed in 2004—ahead of schedule, on budget, and with an accident-free safety record. Based on a design–build approach to construction, the building optimizes quality, number of office spaces, and amount of square feet obtained for a fixed price ($4.9 million). This new facility, Building 142, provides space for more than 100 personnel relocated from substandard trailer facilities. Two more FIRP Replacement Office Building projects of similar scope are under way, with scheduled completion in fiscal year 2005. In addition, the new Central Café opened in February 2004. It can serve nearly twice the number of daily lunches as the 22-year-old "temporary facility" it replaces. The café offers marked improvements in operational efficiency and the overall dining atmosphere. The Central Cafeteria Replacement Project also used a design–build approach with a budget under $5 million.

Four acres of buildable space in the Laboratory's core national security area became

Construction under way at Building 142. This building, now complete, was the Laboratory's first Replacement Office Building Project.

available with completion of the Building 222 Decontamination and Demolition Project. Removal of the contaminated, 50-year-old chemistry laboratory was funded by FIRP. The project compiled an outstanding safety record and rivaled industry's best in class with average demolition costs under $200 per square foot. Demolishing Building 222 eliminated more than $13 million of deferred maintenance, avoided $3 million in compliance upgrades, and saved nearly $1 million in annual surveillance and maintenance costs.

A Model for DOE Facilities Management Practices

Intelligent Sustainment and Renewal of Department of Energy Facilities and Infrastructure, a National Research Council report issued in 2004, states that "the Committee was impressed with the management initiatives undertaken at LLNL toward establishing effective progress and priorities, and with progress made in their implementation." The report goes on to say that "implementation of Real Property Asset Management throughout the DOE would be enhanced if all department sites used LLNL practices and processes as models."

The effort to cope with increasing deferred maintenance began nearly a decade ago. The Laboratory launched a strategic, corporate approach to addressing the problem, whose success was documented for DOE in a 2003 report. By applying a set of processes developed internally and based on other successful government and industrial organizations, the Laboratory succeeded in stabilizing its deferred maintenance well in advance of the NNSA-wide stabilization goal of fiscal year 2005. With FIRP funding, Livermore is now decreasing its $300-million-plus backlog and is committed to the goal of reaching industry standards of good or better.

Reviewing plans for maintenance of Laboratory facilities.

A Commitment to Process Improvement

Excellence in operations and business practices requires continual efforts to improve effectiveness and productivity while minimizing costs and unnecessary administrative burdens. Over the last several years, the Laboratory has instituted streamlined, electronic processes for a wide range of business and administrative functions. Other significant process improvements in the areas of security and facilities management, discussed above, have earned the Laboratory outside recognition. Because of the importance of achieving continual improvement in all Laboratory activities, Livermore management launched a Process Improvement Initiative in 2004.

The initiative is serving as a catalyst to stimulate continual improvement as a shared Laboratory value, and it is helping organizations to identify key opportunities and needs for process improvement. Livermore staff members are being trained in formal methods for process improvement by outside experts. Process owners benefit from these facilitators and methods as they improve efficiencies in functions that cut across Laboratory organizations. As examples, process improvement efforts are under way to improve Badge Office services, implement a number of information technology initiatives, and better manage issues associated with the presence of foreign nationals at the Laboratory.

Outreach and Partnering

Outreach and Partnering

With outstanding scientific and technical capabilities and an important national security mission, Lawrence Livermore National Laboratory is a national resource. The Laboratory's continuing success depends on engaging sponsors and actively participating in the broad scientific community to understand emerging national needs and technical opportunities. Success in the Laboratory's research programs depends on strong ties to research universities and partnerships with U.S. industry.

The Laboratory's closest academic ties are with campuses of the University of California (UC). In addition to more than 500 ongoing collaborations between Laboratory scientists and UC colleagues, joint research centers foster interdisciplinary collaborations. These academic partnerships strengthen research programs at Livermore and the campuses. University ties also serve as a valuable pipeline for recruiting new talent to the Laboratory. Partnerships with U.S. industry bring valuable research tools to Livermore programs—from the world's fastest computers to the world's largest laser. Industrial partnerships also lead to the transfer of the Laboratory's technological advances to the marketplace.

Lawrence Livermore is an important regional resource, too, contributing to the intellectual vitality of the San Francisco Bay Area and the San Joaquin Valley. Being a good neighbor is important to the Laboratory and its employees. As an institution, the Laboratory provides Californians with information and expertise on a variety of issues ranging from homeland security to groundwater management. Livermore also partners in an array of educational, business development, and diversity outreach programs. The Laboratory supports a wealth of K–14 science education programs and works with local universities and colleges to provide high-technology workforce training. As individuals, the Laboratory's more than 8,000 staff members and their families contribute to the well-being of neighboring communities through charitable contributions and volunteer work.

A Good Neighbor

In June 2004, more than 150 community guests conversed with Laboratory managers and staff and toured research facilities as part of Lawrence Livermore's Community Leader Day. Tour stops included opportunities to learn about projects in homeland security and bioscience and to visit facilities for supercomputing, forensic science, mass spectroscopy analysis, and atmospheric release response. The day provided guests a broad view of the Laboratory and its relationship to local communities. As highlighted in the Director's welcoming talk, Livermore partners with its neighbors in many ways: security and emergency planning, transfer of technology to private industry, contracts with local businesses, interactions with educators and students, and support of local nonprofit organizations through the annual Help Others More Effectively (HOME) campaign.

The Laboratory's HOME campaign raised more than $1.6 million for Bay Area and San Joaquin Valley charitable organizations in 2004. Livermore employees marked their seventh straight year of record-setting contributions. The Laboratory is the largest single workplace supporter of the Tri-Valley Community Fund, which is dedicated to raising and distributing local charitable contributions to human service, educational, cultural, and recreational organizations.

Employees also engage in many outreach activities through participation in community assistance and economic development organizations. The Laboratory's *Community Report*, issued in June 2004, summarizes the many ways the institution and Livermore employees benefit neighboring communities. The report is available from the Public Affairs Office and online.

Local leaders visit the Forensic Science Center as part of Community Leader Day.

Christmas donations are among the many ways that Laboratory employees generously contribute to the community.

Edward Teller Education Center

The Laboratory hosted the fifth annual Edward Teller Science & Technology Education Symposium in September 2004. Attended by over 200 California teachers, the two-day event gave participants up-to-date science information in topical areas as well as lessons and activities that can be used in the classroom. Attendees toured Livermore laboratories in their chosen topical area, participated in discussions about recent research achievements with Laboratory scientists and engineers, and worked side by side with researchers in hands-on activities developed for classroom application.

The symposium was held at the newly opened Edward Teller Education Center, which is home for a variety of professional development programs for K–14 educators. Sponsored by the Laboratory, the UC Office of the President, UC Davis, and UC Merced, the center aims to improve the quality of science instruction and technology applications in the classroom. Other activities at the center in 2004 included 12 computer technology workshops (up to 25 teachers in each) and a Teacher Research Academy in

July—three- to five-day training programs for more than 100 teachers—in the areas of biotechnology, biophotonics, and environmental science.

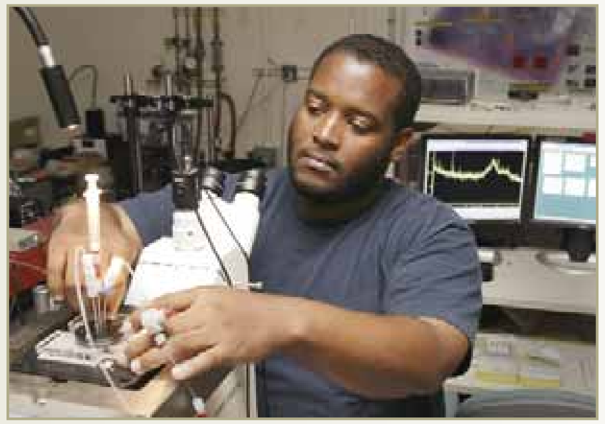
Science on Saturday, a five-week series of lectures by Laboratory researchers before standing-room-only audiences, is one of Livermore's student enrichment programs. The program has been extended to the San Joaquin Valley in collaboration with Merced College and UC Merced. In July, a one-day "Got Science? Discover Science Saturday" attracted over 2,000 people to the Laboratory for a family-oriented science extravaganza.

Livermore staff also travel to schools around the Bay Area and the San Joaquin Valley to conduct interactive science presentations and demonstrations in chemistry, physical science, and environmental science. The presenters engage students in discussions about scientific and technical concepts through hands-on experiments to stimulate scientific thinking and enhance learning skills. Other outreach activities include a tour available to fourth- and fifth-grade school classes and sponsorship of science and engineering fairs and a math challenge. Overall, Livermore's K–14 projects engage approximately 10,000 students each year.

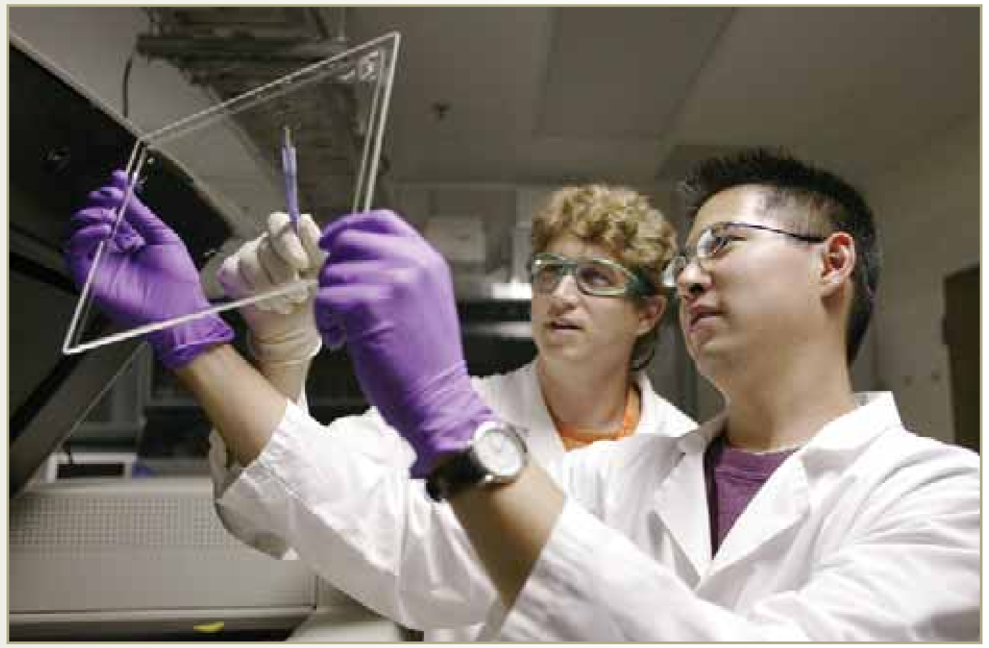
Research Collaborations with University of California

Many mutually beneficial collaborations between the Laboratory and UC campuses serve to strengthen research programs at Livermore and provide the campuses with access to Livermore's multidisciplinary capabilities and special research facilities. More than one-quarter of the roughly 1,000 peer-reviewed journal articles produced each year by Laboratory scientists are coauthored by colleagues at UC campuses.

One collaborative study, published in 2004 after five years of research, offered direct benefit to the UC system. It was supported by the Campus–Laboratory Collaborations Program, which is funded by the compensation UC receives for managing Department of Energy laboratories. The seismic hazards to buildings at three UC campuses were studied in detail in a multidisciplinary project initiated by a Laboratory scientist and involving researchers from many of the campuses. The results indicate that current methods for estimating the ground-shaking effects of major earthquakes could lead to significant underestimates of their severity and inadequate seismic protection.



Above, students with Oakland's Curriculum for Urban Research Environmental Concerns visit the Laboratory. At right, a summer Department of Homeland Security fellow (right) works with a Laboratory researcher.



Outreach and Partnering

The Laboratory has especially strong ties with UC Davis dating from the 1963 establishment of the Department of Applied Science campus at Livermore. Other major collaborations now include the Center for Biophotonics Science and Technology and the Integrated Cancer Center (designated a National Cancer Center by the National Cancer Institute). Both are housed at the UC Davis Medical Center in Sacramento. The biophotonics center is the only National Science Foundation-funded center in the country devoted to the study of light and radiant energy in biology and medicine. This collaboration involves about 100 researchers from Livermore, three UC campuses, and other universities. One of the center's many projects that involve Laboratory researchers is the development of laser-imaging technology that will allow surgeons to conduct biopsies to detect subsurface cancer at the operating table.

The Laboratory is also assisting in the establishment of UC Merced. It will be the nation's first new public research university of the 21st century. When fully developed, the UC Merced campus will be home to 25,000 students and 6,600 faculty and staff. The fledgling university already has a close affiliation with Livermore, and its research areas are being aligned with the Laboratory's

A collaboration between the Laboratory and the University of California conducted seismic studies at three campuses.

A graduate student from Fisk University uses Raman spectroscopy, a biophotonics tool, to study an antifreeze protein found in arctic fish.

Postdocs Give the Laboratory High Marks

The Laboratory is one of the nation's best workplaces for postdoctoral fellows, according to a 2004 survey conducted by *The Scientist* magazine. Survey participants ranked Livermore seventh among 61 U.S. institutions on such factors as access to publications and journals, high-quality research tools, scientific career preparation, communication and collegiality, and quality of research. The results were based on responses to a Web-based questionnaire from more than 3,500 researchers in tenured and tenure-track positions.

Livermore is home for approximately 150 postdocs, 75 graduate students on term appointments, 200 students on temporary appointments, and 400 to 500 students as summer interns. Engaging students during their educational career is an important element of Livermore's strategy for recruiting needed critical skills. Over the past decade, approximately 45 percent of the graduating Student-Employee Graduate Fellowship students have continued as Laboratory employees.

Lawrence Livermore National Laboratory

in a number of areas. In this strategic collaboration, Livermore is helping in the recruitment of science and engineering faculty. As with other UC campuses, some members of the UC Merced faculty are expected to also have appointments at Livermore. At the same time, Laboratory researchers are being encouraged to become adjunct faculty at UC Merced.

The Laboratory's five University Relations institutes foster many additional research collaborations with UC campuses and other major universities. The first institute, established in 1982, is Livermore's branch of the Institute of Geophysics and Planetary Physics (IGPP), which is linked to similar units on several campuses and is one of the leading geoscience and astrophysical research centers in the world. IGPP's astrophysics efforts received wide recognition through the MACHO (massively compact halo objects) project and the development of laser guide star technology (see p. 26). The Laboratory's first IGPP director, Claire Max, winner of a 2004 E. O. Lawrence Award, is now deputy director of the Center for Adaptive Optics at UC Santa Cruz. Funded by the National Science Foundation, the center includes 27 partnering institutions including Livermore and several UC campuses.

Laboratory Technology in the Marketplace

In 2004, Livermore scientists and engineers—and their research partners—earned five R&D 100 awards (see p. 49). Each year, *R&D Magazine* presents awards to the 100 top technological advances of significant potential benefit to society. Since 1978, Laboratory researchers have won 102 R&D 100 awards, and many of these inventions were developed in partnerships or have been transferred to U.S. industry for commercial development. Through license agreements, numerous Laboratory-developed products are now in the marketplace, earning licensees revenues estimated at more than $100 million. One Laboratory invention, the micropower impulse radar, has already led to 16 licenses for diverse applications. Other licensee products range from medical diagnostics, flow cytometers, and a clinical radiation treatment system to laser crystals, laser peening, diffraction gratings, and items incorporating microlenses. In addition, Laboratory-developed software is being used by commercial entities through more than 100 licenses.

A notable success is the rapid transfer to the industrial sector of technologies to increase homeland security. These include Cepheid's GeneXpert, which is the heart of biohazard detection systems at U.S. Postal Service mail sorting centers; CDT Systems' mobile water treatment system for emergency clean water supply; Ho'olana Technologies Alu Like Enterprise's chemical detection field kit; and MFSI's biolyser for spores, bacteria, and viruses.

Another product for homeland security won a 2004 Excellence in Technology Transfer Award from the Federal Laboratory Consortium (a network of more than 600 national laboratories from 16 federal agencies). This was Livermore's RadScout radiation detector, which has been commercialized as the ORTEC Detective. Negotiations were completed with ORTEC in late 2002. Livermore supplied ORTEC with engineering drawings, specifications, software, and patents for the detector, which can accurately distinguish among different types of radioisotopes. Agreements were formally signed in spring 2003, and the commercial version was available for sale just five months later. The first units were delivered to customers in March 2004. Security personnel nationwide now have access to easy-to-use radiation detectors that can screen luggage and shipping containers and report results on the spot (see p. 16).

A radiation detector for homeland security is being marketed as the ORTEC Detective.

People and Management

People and Management

Livermore's most valuable asset is its workforce.

The Laboratory stays vibrant by attracting and retaining a high-quality workforce motivated by "passion for mission" and dedicated to excellence. Highly motivated individuals and exceptional multidisciplinary teams are responsible for achieving program goals, advancing science and technology, and continually improving operations. Laboratory staff are carrying forward a long tradition of scientific and technological innovation and delivery to sponsors of markedly improved capabilities to meet pressing national needs. The strength of the current workforce is demonstrated by the many awards and honors they received for their scientific accomplishments and quality operations.

The Laboratory's long-standing association with the University of California (UC) has fostered a tradition of intellectual independence and integrity as well as a focus on the long-term interests of the nation. Laboratory researchers strive to anticipate future national needs and security threats. Science and technology investments and exploratory research and development efforts are targeted accordingly. In addition, strong ties to innovative research activities at UC campuses serve as a vehicle for bringing new talent to the Laboratory.

Much of Livermore's work requires special skills, and expertise is gained through years of training, working with senior staff, and access to unique computational and experimental capabilities. The Laboratory's continuing success depends on providing employees with abundant career development opportunities, a quality work environment, and the chance to work on projects that make a difference to the nation. Visionary technical leadership and effective management of research programs and operations underpin Livermore's achievements and sustain public trust in the Laboratory.

Contract Competition for Los Alamos and Livermore

University of California faculty members issued a strong endorsement of UC's continued management of Lawrence Livermore and Los Alamos national laboratories. In an electronic survey completed in May 2004, two-thirds of the participating members of the UC Academic Senate said UC should submit bids to retain the management contracts. UC has managed and operated Berkeley, Livermore, and Los Alamos national laboratories on behalf of the federal government since each laboratory's inception. UC has provided the stable, special environment that has enabled the laboratories to make many remarkable scientific achievements and vital contributions to national security. According to the poll, the major reasons for faculty support are the quality and national benefits of the laboratories' unclassified research and the benefits to faculty and students of research collaborations with Livermore and Los Alamos.

In 2003, the Department of Energy (DOE) announced its intention to open the management of Los Alamos to full competition at the expiration of the current contract, which happens on September 30, 2005. Subsequent congressional legislation requires that the management contracts for all three UC-managed national laboratories be subject to open competition. The contract to manage and operate Livermore also expires on September 30, 2005; however, the National Nuclear Security Administration (NNSA) has the authority to extend the contract up to two years. The UC Board of Regents has not made a decision whether to compete for the Livermore and Los Alamos contracts, but has taken actions that allow UC to preserve its options and to continue to prepare as if it will compete.

New Faces in the Director's Office

Retirements in the Director's Office set the stage for the introduction of a new leadership team for the Laboratory at the beginning of 2005. Both Glenn Mara, deputy director for operations, and Harold Graboske, acting deputy director for science and technology, left the Laboratory in 2004 after a combined 68 years of service. During that time, they made many outstanding contributions to the success of the Laboratory.

Cherry Murray, deputy director for science and technology.

Wayne Shotts, deputy director for operations.

In September 2004, Cherry A. Murray was appointed deputy director for science and technology by the UC Board of Regents. As deputy, she has overall responsibility for the quality and health of Laboratory-wide science and technology as well as management responsibility for an investment portfolio of more than $100 million, including the Laboratory Directed Research and Development Program. Murray began her new assignment on December 1 after leaving Bell Labs, Lucent Technologies where she served as senior vice president for Physical Sciences and Wireless Research. A nationally recognized physicist, Murray is a member of the National Academy of Science, the National Academy of Engineering, and the American Academy of Arts and Science. *Discover* magazine named her as one of the "50 Most Important Women in Science" in 2002. In December 2004, Murray was named winner of the American Physical Society's prestigious George Pake Prize for 2005.

Wayne Shotts was appointed deputy director for operations by the UC Regents in January 2005, having served as acting deputy since Mara's retirement in September. Shotts brings to the assignment wide-ranging experience in both programs and operations after a long career at the Laboratory, including the last 10 years as associate director for Nonproliferation, Arms Control, and International Security. He concurrently headed the Homeland Security Organization at the Laboratory since it was formed in 2002. Shotts is setting his sights on improving work processes and quality assurance by developing a strategic, institutional view of Laboratory operations to set priorities, find integrating solutions, and measure overall success.

Murray, Shotts, and Laboratory director Michael Anastasio have initiated a series of activities to develop a shared strategic vision of the Laboratory in 2025—its missions and sponsors, operations, workforce, science and technology, and partnerships. In the coming year, the senior management team will work with future scientific, programmatic, and operations leaders across the Laboratory to formulate and implement a set of strategic initiatives to achieve defined goals for 2012 along a trajectory to this long-term vision.

Attention to Workforce Management

Because of the importance of maintaining Laboratory staff quality, the director holds a series of workforce reviews each December. These reviews examine personnel issues in all Laboratory program areas, and they scrutinize the effectiveness of Livermore's human resource strategies to strengthen recruitment and retention programs. Each directorate shares workforce data, including overall capability and critical skills, diversity, performance and salary management, employee development and succession planning, work environment, safety and security, and progress in institutional initiatives. The results of the reviews serve as the basis for developing strategies to ensure an optimal workforce to meet the Laboratory's needs.

Human resource professionals work with the directorates to develop an integrated strategy for recruiting talented individuals to the Laboratory. The UC campuses are an important focus for recruitment. Ongoing activities with UC and other major research universities serve as a pipeline to fulfill needs for critical skills (see p. 42). Workforce diversity is also an important goal of recruitment efforts. In 2004, the Computation Directorate was recognized by DOE for its development and implementation of a multifaceted plan to recruit underrepresented computer scientists to the Laboratory. People at all levels in the directorate and human resources experts at Livermore participate in recruitment activities, which earned a DOE Equal Employment Opportunity/Diversity Best Practices Award.

Livermore's comprehensive programs aimed at leadership and management development are recognized as one of the best in class within the UC system and the DOE complex. The core program includes two training courses for supervisors—a Management Institute class designed to help prepare next-generation leaders and a variety of short courses. Over 1,400 supervisors have been trained to date, and there are 125 alumni of the Management Institute, a two-and-a-half-day program presented by the director and his senior management team. In addition, over 500 employees have participated in customized leadership development programs established in most of the Laboratory's directorates. Other opportunities are available to all employees through onsite and external courses and the Leadership Lecture Series.

In 2004, the Laboratory implemented phase 2 of its Integrated Pay and Performance Program (IPPP), the largest revision of Livermore's performance appraisal, ranking, and pay system in the last two decades. The program is designed to be more consistent throughout the Laboratory and less complex than previous performance management approaches. IPPP links total contribution to Laboratory programs and operations more directly to pay, and it holds management accountable for effective program implementation.

The burgeoning careers of two Laboratory scientists, Edmond Chow and Christine Orme, are recognized by the Presidential Early Career Award for Scientists and Engineers.

People in the News

The scientific and technological accomplishments of Livermore employees are recognized outside the Laboratory by prizes, awards, and front-page publicity. But science isn't the whole story. Many other individuals and teams at the Laboratory have also been recognized for their contributions.

Laboratory scientists and engineers were responsible for 157 invention disclosures, 102 U.S. patent applications, 14 first foreign patent applications, 94 issued U.S. patents, and 9 issued foreign patents in fiscal year 2004.

Livermore astrophysicist Claire Max was one of seven winners of DOE's E. O. Lawrence Award. Then-Secretary of Energy Spencer Abraham presented the award in Washington, D.C.

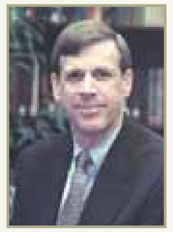
Deputy director for science and technology Cherry Murray was named the winner of the American Physical Society's George Pake Prize. Murray joined the Laboratory on December 1.

In winning a Presidential Early Career Award for Scientists and Engineers, computer scientist Edmond Chow was honored for research into preconditioning methods for discretized partial differential equations that enable scientists at Livermore to perform implicit simulations that were previously impossible. Physicist Christine Orme was recognized for her work in understanding the physical mechanisms of biomineralization and the development of force microscopy-based methods of investigating mineralization at the nanoscale.

Five teams of Laboratory scientists won R&D 100 awards, known as the "Oscars of Invention." Each year, *R&D Magazine* selects the 100 most technologically significant new products and processes, ones that are likely to be the most beneficial to the world at large. The five awards were for:

- Autonomous Pathogen Detection System, an automated, lectern-sized instrument that can monitor the air for all three types of biological agents—bacteria, viruses, and toxins.
- Diode-Pumped Pulsed Laser for Mine Clearing, which uncovers and neutralizes buried land mines.
- Inductrack, a magnetic levitation system for transportation. It uses new arrangements of permanent magnets to create its levitating fields.
- Chromium, a software program that provides a way for interactive two-and three-dimensional graphics applications to operate on clusters of personal computers.
- SiHybrids, a molecule of DNA and RNA that interferes with genes to "silence" them or turn them off.

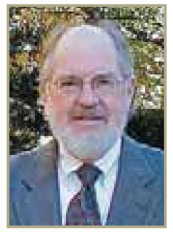
The U.S. Air Force honored three Laboratory employees with its Exemplary Civilian Services medal, the highest of three Air Force civilian service awards. Awardees were Larry Altbaum, Bruce Goodwin, and George Sakaldasis (third, fourth, and fifth from left).



Director Emeritus Bruce Tarter received DOE's Gold Award, its highest honorary award, in recognition of his achievements, services, and outstanding leadership while he served as Laboratory director.

Five Laboratory scientists were named fellows of the American Physical Society:

- Tina Back was honored for the quantitative application of x-ray spectroscopy that has advanced the understanding of high-energy-density plasmas in the areas of x-ray hohlraums, radiation transport, and high-efficiency radiation production.
- Tom Rognlien was elected for seminal contributions to the modeling of tokamak edge plasmas and their interaction with bounding surfaces and to the understanding of heating and transport in collisional and RF-excited plasmas.
- Craig Tarver was recognized for his contributions to shock wave physics, in particular, his theoretical work and for developing and implementing models of the detonation of energetic materials.
- Louis Terminello was honored for his innovative use of synchrotron radiation spectroscopies to reveal the electronic and atomic structure of new materials.
- David Eaglesham, who left the Laboratory in January 2005, was cited for his seminal discoveries and technical leadership in semiconductor crystal growth and structural defects in epitaxial materials.



Engineer Ray Stout was named a fellow of the American Society of Mechanical Engineers. Because of his experience in managing radioactive waste, he has also been invited by the French Commissariat a l'Energie Atomique to be a member of an international scientific advisory board for France's nuclear waste storage and disposition program.

Physicist David Chambers was elected a fellow of the Acoustical Society of America for his contributions to time-reversal processing methodology.

Engineer Jerry Lin was named a fellow of the American Society of Mechanical Engineers, recognized for his pioneering work in computational mechanics, including contact algorithms, mixed time integration, element eigenvalue theorems, and element technologies that have been used in many finite-element codes.

In recognition of his recent achievements in plasma physics, Siegfried Glenzer received a Humboldt Research Award. He was one of a hundred scientists from around the world to be so honored.

Physicist Camille Bibeau received the national 2004 Excellence in Fusion Engineering Award from the Fusion Power Associates.

The Alameda County Women's Hall of Fame named physicist and former astronaut Tammy Jernigan its 2004 Outstanding Woman of the Year in the science category.

The Academy of Certified Hazardous Materials Managers (ACHMM) recognized radiological characterization analyst John Wolf with its Young CHMM of the Year Award. Wolf was one of four recipients of this award.

Engineer Ted Saito (center, below) received the Exceptional Public Service Award from the Department of Defense for his work in nonproliferation policy during an assignment at the Pentagon from September 2002 to June 2004.

Tom Isaacs was one of two non-Canadians named to the Assessment Team of the Nuclear Waste Management Organization of Canada, which analyzed options for disposition of Canada's spent nuclear fuel.

Two teams won Laboratory Science & Technology awards, Livermore's highest award for achievement in science and technology. One team developed the processing methods and tooling that produced both the world's largest multilayer dielectric reflection grating and the world's highest laser damage-resistant gratings. This technology provides optics for high-energy short-pulse lasers. The second team was honored for its discovery of bucky-diamond and for unraveling the atomic structure of silicon and germanium nanoparticles.

John Lindl, Doug Wright, and Allen Christian were awarded 2004 Edward Teller Fellowships to pursue self-directed research. Lindl is a recognized leader in fusion energy and the physics of inertial fusion targets. Wright has been instrumental in the discovery of an asymmetry in the time distribution of the decay of B and anti-B mesons. Christian has made major advances in cancer research, bioengineering, and forensic analysis.

A paper on the Laboratory's Autonomous Pathogen Detection System was deemed the "most intriguing" by the Chemical Abstracts Service, a division of the American Chemical Society. It stood out among 200,000 documents reviewed in the fourth quarter of 2003.

Richard Snavely, a postdoctoral fellow, was honored by UC Davis with the Allen G. Marr Distinguished Dissertation Award. He won the prize for a dissertation entitled "Physics of Laser-Driven Relativistic Plasmas, Energetic X-Rays, Proton Beams and Relativistic Electron Transport in Petawatt Laser Experiments." He performed his research on the world's first petwatt laser at Livermore's former Nova laser.

In a survey conducted by *The Scientist* on the best workplaces for postdoctoral researchers, the Laboratory ranked seventh among 61 institutions. Livermore was one of five federally funded research facilities among the top 15 on the list.

Fisk University in Nashville, Tennessee, received a National Science Foundation Center of Excellence for Research in Science and Technology Award to establish a Center for Physics and Chemistry of Materials. The Laboratory's Research Collaborations Program for Historically Black Colleges and Universities and Minority Institutions was instrumental in helping Fisk obtain this award.

Security was the watchword when the Laboratory's Operational Security program took third place among 81 nominees in the 2004 National Operational Security awards. At about the same time, the Computer Incident Advisory Capability received a certificate of appreciation and recognition from DOE's chief information officer.

Laboratory firefighters were recognized by NNSA for their heroic actions in fighting southern California wildfires in 2003. The Laboratory dispatched three strike teams and 10 firefighters to the fires.

A Computation Directorate program to recruit underrepresented computer scientists to the Laboratory received a DOE 2004 EEO/Diversity Best Practices Award.

A radiation detection system whose development and commercialization was speeded up at the request of the Department of Homeland Security won an Excellence in Technology Transfer Award from the Federal Laboratory Consortium. The system, known as RadScout at the Laboratory, has been commercialized by Advanced Measurement Technology, of Oak Ridge, Tennessee, as the ORTEC Detective.

Engineer Jose Hernandez was selected by the National Aeronautical and Space Administration (NASA) to join the 2004 Astronaut Candidate Class. He has been on leave from the Laboratory and working at NASA since 2001.

The Protective Force Division, Security Police Officer Team garnered third place overall in the annual DOE complex-wide Security Police Officer Training Competition. The event was held at the Savannah River Complex near Aiken, South Carolina. Later in the year, the Laboratory's Special Response Team finished 10th out of some 30 government agency teams in a SWAT invitational tactical competition.

Livermore's Transportation Systems Management Program received a 2003 Federal Energy and Water Management Award from DOE and the Federal Interagency Energy Policy Committee as well as DOE's 2003 Departmental Energy Management Award for its energy conservation programs.

A training video, "Soil Excavation and Concrete Penetration Permit Process and Awareness at LLNL," garnered a Government Video Star Award in the training category at the Government Video Technology Exposition. The video was developed by Plant Engineering's Permit Office and Damage Prevention Team. This team was also featured in the July 2004 issue of *Underground Construction* for Livermore's zero tolerance for damage to underground facilities. The magazine recognized Livermore as a model for underground location and damage prevention.

The Public Relations Society of America honored two Laboratory teams with communication awards. One was for a short video, "Edward Teller Remembered," and the other was for a homeland security press kit.

Linda Dibble was recognized by the San Joaquin Engineering Council with its 2004 Distinguished Service Award. Over the years, she has volunteered in numerous science-related educational outreach programs in San Joaquin County.

Patricia Axelrod, cochair of the 2003 HOME campaign, was honored by the San Francisco/East Bay Branch of Community Health Charities of California as Outstanding Chairperson of 2003.

Ron Hafner was the only California recipient of the National Weather Service's annual Holm Award. He was one of 25 honorees from across the country, all of whom are volunteer collectors of weather data. He has been collecting weather data at his Livermore home since 1981.

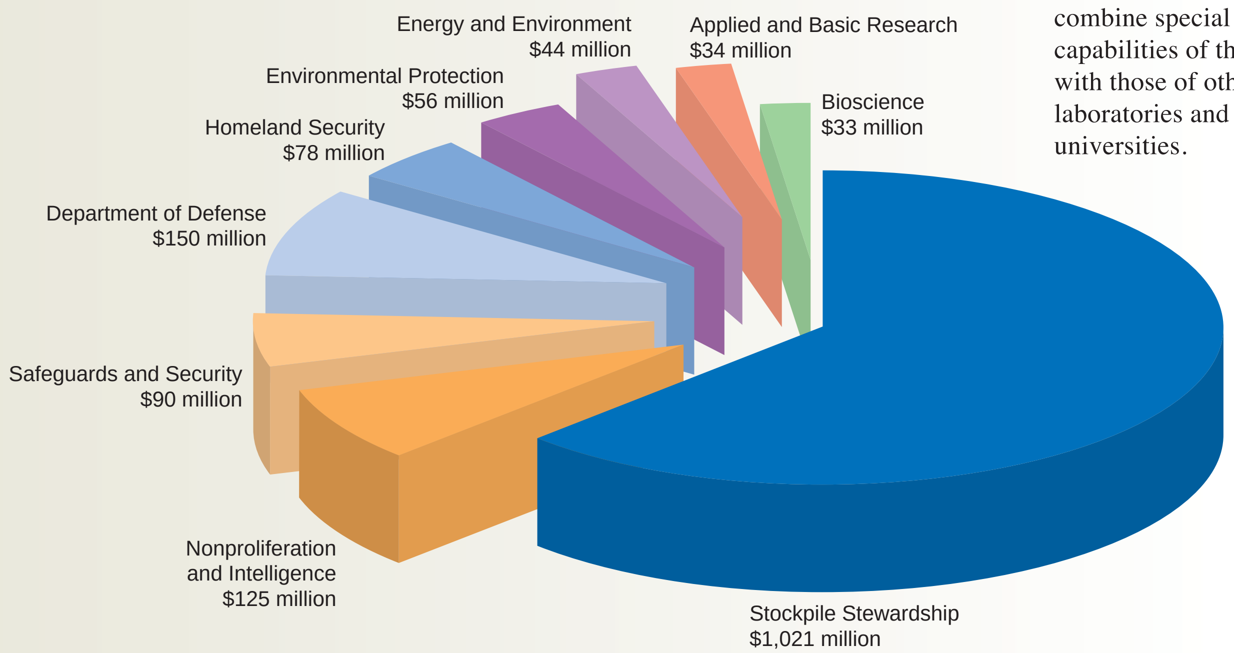
Laboratory Budget

Most of Livermore's $1.6-billion budget for fiscal year 2004 was designated for research and development activities in program areas supporting the Department of Energy's (DOE's) missions.

As a national security laboratory, Livermore is part of DOE's National Nuclear Security Administration (NNSA). The Laboratory's funding largely comes from the NNSA Office of Defense Programs for stockpile stewardship activities. Support for national security and homeland security work also comes from the NNSA Office of Defense Nuclear Nonproliferation, the Department of Homeland Security, various Department of Defense sponsors, and other federal agencies.

As a multiprogram laboratory, Livermore applies its special capabilities to meet important national needs. Activities sponsored by non-NNSA parts of DOE include work for the Office of Environmental Management as well as research and development projects for the Office of Science and many other program offices. Non-DOE sponsors include federal agencies (such as the National Aeronautics and Space Administration, Nuclear Regulatory Commission, National Institutes of Health, and Environmental Protection Agency), State of California agencies, and industry.

Many of the Laboratory's research and development activities are pursued for sponsors as partnerships that combine special expertise and capabilities of the Laboratory with those of other DOE laboratories and research universities.



Find Out More about Us

Visit the Laboratory's recently redesigned and frequently updated Web site at http://www.llnl.gov/. Learn more about our many scientific and technical programs. Discover the many opportunities for employment, academic research, and industrial partnerships. Keep posted on the latest news.

Read about our accomplishments each month in our award-winning magazine, *Science & Technology Review*. The magazine is available on the Web, and you can use the Web site to order a print subscription.

The Laboratory is celebrating the World Year of Physics 2005. Look for news and events on our Web site and in feature articles in *Science & Technology Review*.

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2004 Annual Report

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